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Materials Recycling

An Overview of the Sixth Mineral Waste Utilization Symposium

Compiled by S. A. Bortz and K. B. Higbie

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNITED STATES DEPARTMENT OF THE INTERIOR
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PREFACE

The United States, as a modern industrialized nation, is the product of constantly advancing technology. Our mobility, our affluence, and our high overall standard of living are manifestations of technological progress. So is solid waste pollution.

Technology can and does create pollution. Fortunately, it can also be applied to control and abate this pollution. From an environmental standpoint, the handling, discharge, and conversion of solid waste are obviously of public concern, and in these days of energy shortage, we can no longer ignore the importance of solid wastes, no matter what form they take--industrial, mining, agricultural, or domestic. The objective of the Sixth Mineral Waste Utilization Symposium was to be of service to those who are sincerely concerned in both energy and environment, and who wish to share their views on the recycling and disposal of solid wastes. The symposium was attended by 126 persons, 18 of whom were from outside the United States.

Recycling is an economic phenomenon. The extent to which a given material is recycled is a function of the values of so-called secondary materials in relation to so-called virgin materials. These relative values can change as a result of many factors, including changing technology, tax policies, transportation, and new applications. It was the theme of this symposium to look at both technical and economic factors, to describe progress over the last 10 years, to point out problems resulting from utilization of solid wastes, and to suggest new solutions to these problems.

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MATERIALS RECYCLING

An Overview of the Sixth Mineral Waste Utilization Symposium[1]

Compiled by

S. A. Bortz[2] and K. B. Higbie[3]

ABSTRACT

This Bureau of Mines report reviews the information presented at the Sixth Mineral Waste Utilization Symposium cosponsored by the Bureau of Mines, U.S. Department of the Interior, and the IIT Research Institute. Environmental scientists and engineers from nine countries participated in the symposium, which was held May 2-3, 1978, at the Chicago campus of IIT Research Institute. The 56 papers presented on the reclamation and recycling of mining and mineral wastes, municipal solid waste, industrial wastes, and scrap metal are summarized herein.

[1]The complete papers and additional bibliographic information can be found in the Proceedings of the Sixth Mineral Waste Utilixation Symposium published jointly by the U.S. Bureau of Mines and IIT Research Institute. Inquiries regarding individual papers should be directed to respective authors. Inquiries regarding the overall symposium should be directed to the U.S. Bureau of Mines, Director, Division of Mineral Resources Technology, Department of the Interior, Washington, D.C. 20241. Copies of the Proceedings of the Sixth Mineral Waste Utilization Symposium can be obtained by sending a check for $30 each to IIT Research Institute, P.O. Box 4963, Chicago, Illinois 60680.

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TOTAL RESOURCE RECOVERY

by

R. C. Kirby[1]

Introduction

Nature concentrated her riches in complex deposits around the world. It is our challenge to discover and use them wisely. True conservation means maximum employment of our resources--and minimum waste. Total resource recovery implies the utilization of all materials extracted from the ground. Consider, for the moment, the Mascot mines in Jefferson City, Tenn. There, the deposit contains 4 pct zinc and over 95 pct limestone. The ore is mined and concentrated for zinc recovery. The tailings from flotation are dried and sold as agricultural lime. The float-sink reject is sold as crushed stone. The mine and mill recover, for economic use, nearly all of the rock extracted from the Earth's crust. Total resource recovery is approached.

Without total recovery we will have to find a way to renew nonrenewable resources. Part of the answer lies in secondary resource recovery and mineral waste utilization. We are meeting at the sixth symposium in this series cosponsored by the Bureau of Mines to address part of the problem. At this symposium we should review not only what we have learned in the last 2 years, but also what has been learned in the 10 years since the first symposium. Where have we made progress? Where have we failed? And what can we do to more closely approach total resource recovery? We hope that this symposium will serve as a forum to answer these questions.

To set the stage for this look backward as well as forward, I want to examine the current state of resource recovery technology, technology development needs, and appropriate roles for various segments of society in meeting those needs.

The Problem Defined

In meeting society's needs for metals, minerals, and fuels, the extractive and basic materials industries have had to treat progressively lower grade ores. The average copper ore, at the turn of the century, was 3 pct copper. Today, it is less than 1 pct. Iron ore, at the turn of the century, was so rich that it needed only to be mined and shipped to the blast furnace. Further processing was unnecessary. Beneficiation began as washing and screening, and only recently has it begun to include concentration and induration steps.

The demand for more materials, coupled with the necessity for treating lower grade ores, has resulted in an inevitable trend--the production of

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increasing volumes of solid, liquid, and gaseous wastes. The extent to which these wastes are made into usable byproducts represents progress toward total resource recovery. The extent to which they are discarded as useless waste--or even harmful waste--represents the remaining problem. Table 1 quantifies the mineral industry solid waste problem in 1975. Total mineral waste generation from nonfuel minerals now exceeds 2 billion tons per year (3)[2] and exceeds municipal waste generation by a factor of more than 15.

TABLE 1. - Solid wastes generated by the mineral industries

Industry	Bulk weight of waste, million tons per year
Copper	960
Phosphate rock	350
Iron and steel	420
Lead-zinc	23
Aluminum	15
Other	380

Source: Morning (3).

Effluents and emissions, such as acid mine waters and sulfur dioxide, also create problems. Analysis at each major step in the materials system is warranted.

Mining and Concentrating

Mining and concentrating produce the bulk of the wastes generated by the minerals industry: Gangue, tailings, and mine water are the principal problems. These problems have been addressed over many decades with research, development, and commercialization. Several examples of successful resource recovery merit mention.

Recovery of copper by cementation, it should be remembered, began as an approach to more complete resource recovery. It was first practiced in the Spanish copper mines during the 16th century. It emerged in this country as a waste-rock-plus-ferrous-waste system. At Utah Copper, it incorporated a third waste--acid mine water. Today the Utah Copper Division of Kennecott Copper pumps about 60 million gallons of sulfuric acid solution per day over strip mine waste rock at the Bingham pit. This acid is derived from the iron and copper sulfide residues contacted by the waste water. The copper content of a very few pounds per ton of waste rock is dissolved in the acid solution. It is then recovered as cement copper by circulation of the leach solution over "tin" cans where the iron precipitates the copper. Today cementation is used throughout most of the U.S. copper industry and accounts for about 10 pct of our domestic production.

Mine water can also be used. During 30 years of its operating life, Copper Range Co.'s Champion mine supplied water to the city of Houghton, Mich.

[2]Underlined numbers in parentheses refer to items in the list of references at the end of the individual papers.

When the mine was closed, that city acquired control of the water. The "waste" outlived the primary product (1).

Examples of similar successes abound--turning broken marble slabs into ground "whiteners" for paint and plastics applications, using chert from Missouri lead mining for road construction, and extracting uranium from mine waste or phosphate processing streams are three of the many cases.

To illustrate typical problems that remain, phosphate slimes continue to accumulate. Present industrial practice permits recovery of only about two-thirds of the phosphate value. The remainder is lost in the beneficiation waste, especially the Florida clay slimes. Solids in the slimes remain in suspension and do not settle out, resulting in serious environmental problems. The Bureau of Mines is working on a direct acid digestion process for Florida ore that will increase phosphate recovery, as phosphoric acid, to over 90 pct and produce a filter cake that will get around slimes storage problems. If such research leads to commercial practice, it will extend our phosphate reserves significantly and simultaneously reduce the environmental risks of phosphate processing. In addition, other Bureau research and development is aimed at recovering phosphate from existing slime ponds or from newly formed slimes. Slimes would still be formed during beneficiation of phosphate ore for uses other than acid production.

Technology is needed not only for phosphate but also for the reuse of vast quantities of finely ground material which, at present, still accumulates from processing other ores. In the near term, we must improve tailings stabilization--and much work is now going on. In the mid and long term, some of these materials must emerge as useful byproducts to improve total resource recovery. The fundamental need, then, is for technologies that will convert these materials into usable objects--at a cost that makes such processes economically attractive.

It has been our experience that, when processes emerge that are environmentally attractive and economically acceptable, they will be adopted. Certainly widespread use of copper cementation demonstrates this point. The beginnings of a byproduct uranium industry also illustrate that adoption does occur. The keys remain, however: A combination of profit potential and regulation motivates industry to adpot new practices--if conditions are favorable--or constrains industry if it means hindering services to, and performance in, the economy.

Processing and Refining

Ore concentrates, when smelted and refined, yield valuable metals. They also yield a variety of slags, drosses, and offgases. Slags have found a variety of uses--increasing the resources recovered from concentrates. Some drosses are also recycled. Offgases, notably SO_2, are targets for consideration.

Iron and steel slag offers an instructive example of resource recovery. Tens of millions of tons of blast and steel furnace slags accumulated until

after World War II. Modest quantities were used in road construction, cement, and mineral wool. Then a vigorous marketing program coupled with an expanding construction economy solved this disposal problem. Today almost 30 million tons of blast furnace and 10 million tons of steel furnace slags are marketed annually for use in highway and airport construction, railroad ballast, bituminous concrete construction, and cement production. Slags now sell for $4 to $6 per ton.

Some 6.9 million tons of iron and steel slag are produced each year in France, and 3.3 million tons are sold to cement manufacturers there. This slag achieves 75 pct energy savings when used in portland cement (2). In South Africa, half a million tons of Slagment[3] is sold. Sales of Slagment could be higher if more iron and steel slags were available. In Great Britain, a similar product named Cemsave is marketed (2).

Clearly, slags from ferrous metal have been found useful and salable. Similarly, foundry dusts have become valuable byproducts--particularly as soil conditioners. These are examples of resource recovery in its best sense--converting useless wastes into economically sound byproducts. Problems remain in this area, however, which can and should be addressed by research.

Copper smelter slag, although useful in the same manner as steel slag, contains 25 to 35 pct iron. This iron would be useful in the cementation process if it could be recovered in shapes offering the desirable surface-area-to-mass ratio exhibited by tin cans. We have investigated this problem and devised a method on a small scale. If the method is adopted, the economic value of smelter slag could be upgraded.

Bureau of Mines research projects are developing methods for recovering chromium and nickel from ferroalloy flue dusts, stainless steel furnace dusts, mill scale, foundry sand, chrome-bearing refractories, and other materials. Table 2 presents the amounts of these strategic and critical elements that are available as wastes. Success in this effort, if followed by commercial acceptance, could make a significant impact on import dependence.

Emissions, particularly SO_2, present serious problems for smelters. Currently, many smelters recover some of the sulfur dioxide in the form of sulfuric acid. This acid is used within the plant or sold. Smelters, however, can recover far more sulfuric acid than they or their customers can possibly use. Thus, at present, there is a significant waste of sulfur which could be put to useful purposes, such as extending petroleum-based asphalt. With the total resource recovery concept in mind, the Bureau pioneered the citrate process for removing sulfur from stack gas and recovering it in a storable, transportable, and more useful form as elemental sulfur. The recent pilot plant tests at the Bunker Hill smelter demonstrated the technical soundless of this approach. Scale-up of the process, for application to the more dilute stack gases emitted by coal-burning powerplants, is now underway at the St. Joe Mineral coal-fired powerplant outside Pittsburgh.

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[3]Reference to specific trade names or equipment does not imply endorsement by the Bureau of Mines.

TABLE 2. - Chromium and nickel in wastes, tons per year

Source	Cr	Ni
Ferroalloy:		
Flue dusts	3,500	NAp
Slags	1,000	NAp
Stainless steel:		
Furnace dusts	2,500	700
Centerless grinding swarfs	2,000	600
Mill scale	3,600	1,000
Pickle liquid	800	800
Slags	1,000	250
Electrochemical and electrical discharge machining sludges	1,300	2,600
Foundry sand	21,000	NAp
Refractories	19,000	NAp
Etching	4,000	1,000
Plating	2,000	3,900
Catalysts	800	2,500
Chromate and dichromate production	4,000	NAp
Leather tanning	270	NAp
Paint pigment	75	NAp
Textiles	1	NAp
Phosphating metal-coating wastes	NAp	10-20
NiCd batteries	NAp	([1])

NAp Not applicable.
[1]Unknown.

Because establishments in the private sector must remain profitable if they are to supply the economy with both products and jobs, financial incentives and regulatory actions often provide them with stimuli for action. Because the Federal Government promulgates regulations concerning waste disposal and environmental protection, it has the responsibility to help industry find economically sensible solutions. The discharging of that responsibility comes through technical research--with the aid of academic institutions and the active cooperation of industry.

Product Manufacturing

The myriad industrial processes that give us final products all produce scrap. Most of this is generated as prompt industrial scrap and forms the foundation for the $4 billion secondary materials industry. The manufacturing community understands the value of its residues and practices recycling more than any other sector of the economy. Its high resource recovery rate is closely related to a recognition of the economic value of these production residues.

Prompt industrial scrap has the most desirable characteristics (other than home scrap). It is of known chemical composition. Few, if any, unpleasant surprises result from its use. It is generally in a metallic state, which offers energy conservation over processing primary minerals. Capital costs for secondary smelter installations, on an annual capacity basis, are significantly lower than those for primary smelters.

The technologies for using these materials are well developed. The electric furnace and minimill for recovering ferrous metals, the secondary smelters for aluminum, copper, and other nonferrous metals, and the glass furnace charged with 10 to 20 pct cullet are well established.

What is less well established is a smooth economic pattern to stabilize the flow of prompt scrap. Because this scrap provides the marginal increment of raw materials supply necessary for meeting relatively strong levels of demand, its use fluctuates widely. Fortune Magazine dubbed 1974 as "the tinsel days" for scrap dealers--whose products were in extreme demand. The year 1975 could be considered the "tattered days" for the steel mills, and the nonferrous scrap consumers also slashed their purchases drastically.

A useful solution to this problem--on a total basis--may be the development of more technologies where scrap is the basic raw material rather than a marginal increment of supply. Electric furnaces offer this potential for steelmaking--particularly in the minimills. In larger electric furnace establishments, scrap must compete with prereduced iron pellets. The secondary smelters of nonferrous metals, which now recycle their own drosses as well as those from primary smelters, are closer to having scrap as the basic raw material.

Obsolete Wastes

After products have been made and used, they either wear out or become obsolete. They are discarded. In addition to the 135 million tons of municipal solid waste discarded each year, batteries and some 9 million automobiles are junked. Stoves and other household appliances are discarded. Buildings are torn down. The discards of a modern society continue to pile up.

These residues, rejects from our materials system, have commanded the bulk of society's attention in the waste processing area. Table 3 presents municipal processing plants now on-stream. Clearly, such processes have become commercial. And although "bugs" and "glitches" exist, we know how to sort trash into useful components.

In the automobile area, the progress since 1960 has been amazing. The widespread use of shredding technology increased junk automobile recycling to a level of 90 pct. The shredder improved the quality of the ferrous scrap and made it more useful to steelmakers. At the turn of this decade, Huron Valley Steel Corp. developed a sink-float system to handle the nonferrous material from auto shredders. Today, Huron recovers 25,000 tons each of zinc and aluminum annually.

Most lead from scrap auto batteries is reclaimed and recycled by several other firms. Nearly one-half of our annual consumption of lead is met from secondary sources. Despite this progress, technical problems and opportunities in the obsolete scrap area are significant.

An example is the plastics in automobiles. This use of plastics is increasing steadily. By 1980, the average car may contain 400 pounds of

plastics. We are also working on methods to segregate individual plastics economically. This project, being performed in cooperation with Ford and General Motors, has already achieved a promising method for isolating polyurethane foam. Such successes will help achieve systems where plastics are recycled--thus saving valuable petroleum and natural gas feedstocks. These issues must be addressed if we are to approach total resource recovery.

TABLE 3. - Municipal refuse recycling plants

Operational	Size, tpd	Committed or being built	Size, tpd
Ames, Iowa	200	San Diego, Calif	200
South Charleston, W. Va.	200	Hempstead, N.Y	2,000
Baltimore County, Md	1,500	Akron, Ohio	1,000
Chicago, Ill	1,600	Chicago, Ill	1,000
Milwaukee, Wis	1,600	Bridgeport, Conn	1,800
Nashville, Tenn	400	Monroe County, N.Y	2,000
Harrisburg, Pa	720	Pompano Beach, Fla	100
Saugus, Mass	1,200	Tacoma, Wash	500
Norfolk, Va	360	Niagara Falls, N.Y	2,200
Braintree, Mass	240	Newark, N.J	1,000
Ft. Wayne, Ind	300	Lane County, Oreg	500
New Orleans, La	650	Albany, N.Y	750
Franklin, Ohio	150	Duluth, Minn	400
East Bridgewater, Mass	1,200		
Total	10,320	Total	13,450

Society motivates moves in this area of resource recovery from wastes, and advances are coming rapidly. There is sufficient economic and legal incentive to continue this thrust. What appears as an unmet need is the technology to use some of the marginal commodities which emerge from the solid waste stream.

Technology Status

The systems for classifying and separating many product and waste streams are well developed. This holds true at most levels of the materials-processing system. Minor problems and exceptions will always exist, but they are not sufficient to impede meeting our raw material needs.

Numerous systems also exist, and are well entrenched in the U.S. commercial system, to use particular waste products. These include copper cementation, slag usage, secondary smelting of prompt industrial scrap, and the recovery and reuse of metallic elements in junk automobiles. It is popular to say that all resource recovery technology began in the 1960's or--stretching the point--those ancient years, the 1950's. One must pause for a moment, however, and consider that nearly 4,000 years ago, Europe's metals trade was reorganized to insure more complete collection, recovery, and reutilization of bronze scrap. Early American settlers and pioneers had to practice recycling. For instance, old buildings were burned to recover nails. Over a century ago, Charles Dickens was writing about reclaiming values from

"dust heaps" in his book "Hard Times." That those dust heaps could be given as dowries makes a salient point: technologies had developed in response to economic incentive.

Technology Needs

To say that technology has emerged does not imply that such technology is totally adequate. There are both short- and long-term needs that must be met if we are to chart a course toward total resource recovery.

In the near term, we must conceive and create more product development and utilization technologies. What is needed is a clear identification and ordering of priorities for product utilization technologies that can be developed by research.

Over the longer term we must seek out systems to evaluate and develop as many "ore bodies" as possible from this total resource recovery perspective.

Uses for the separated fractions must be developed. Certainly, each new waste-processing operation must be based not on a national perspective, but rather on the marketability of what is separated and recovered. One direction that research and development should take is to assure the usefulness and applicability of materials to reuse in the best form. This is part of the path to renewing nonrenewable resources.

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MINING AND MINERAL WASTES

COMMENTS ON THE UTILIZATION OF MINING AND MINERAL WASTES

by

E. Aleshin[1]

The present accumulation of mining wastes in the United States amounts to over 360,000 tons per day. In the past a total of 23 billion tons has been amassed, and in the future waste will accumulate at a far greater rate. Examples of accumulated quantities and estimated annual production are shown in table 1.

TABLE 1. - Estimated quantities of select mining wastes

Industry	Waste rock, million tons per year	Mill tailings, million tons	
		Annual	Accumulated
Copper	624	234	7,700
Taconite	100	109	3,600
Phosphate	230	[1]54	[2]907
Iron ore	27	27	730
Gold	15	5	450
Uranium	156	5.8	110
Lead	0.5	8	180
Zinc	.9	7.2	180
Aluminum	NA	5	NA

NA Not available.
[1]Includes both phosphate slimes and phosphogypsum.
[2]Includes an estimated 136 million tons of phosphogypsum.

Source: Clifton, J. R., P. W. Brown, and G. Frohnsdorff. Survey of Uses of Waste Materials in Construction in the United States. National Bureau of Standards NBSIR 77-1244, 1977.

Waste rock, which comprises the largest volume of mining wastes, is used as concrete aggregate, mine backfill, subbase, and bituminous paving aggregate. However, compared with the output, very little is utilized.

Coarse mill tailings are stockpiled or put to the same kind of uses as waste rock. Finely divided tailings are piled or stored in ponds. Again, very little is put to use. Taconite wastes, for example, are used in mine roadways; dolomite from zinc ore processing is used as a source of lime in agriculture. Red muds are settled in ponds; although the alkaline solution

[1]IIT Research Institute, Chicago, Ill. (now with PEDCO Environmental, Cincinnati, Ohio).

is decanted for reuse; the solids are not used extensively. Again, the rate of accumulation far exceeds the rate of use.

Much productive research has been performed to show that waste resources can be made into products with satisfactory engineering properties, thus demonstrating that some of these materials have potential in the marketplace. However, very little of this effort has actually resulted in commercialization.

The mining and milling industry produces the greatest volume of unused inorganic wastes, and a greater effort must be made to produce usable products from a larger portion of these wastes. Studies should be initiated to determine the most promising potential uses for mining and mineral wastes, and preliminary economic and environmental analyses should be performed. Research must then begin to develop and improve the engineering properties for the most promising materials.

A number of impediments must be overcome, not the least of which are poor understanding of waste resources by the user (be it manufacturer or ultimate consumer), lack of material and performance standards, and in some instances the cost advantage afforded by some virgin raw materials.

Recognition of these and other impediments and a greater research and development effort by both government and industry will result in increased resources, improvement of the environment, and conservation of energy.

UTILIZING RECOVERED SULFUR IN CONSTRUCTION MATERIALS

by

W. C. McBee,[1] T. A. Sullivan,[2] and H. L. Fike[3]

Sulfur is unique among our mineral resources in that it is one of the few minerals that will be in abundant supply in the future. The Bureau of Mines forecasts potential production of coproduct sulfur in the United States to total 45 million long tons per year by the year 2000. This sulfur will be recovered from the processing of petroleum, natural gas, coal, and other fuels, as well as from smelter gases. During the same year the demand for sulfur is forecast to total only 23 million long tons. Thus, if only half the potential sulfur is recovered, U.S. sulfur needs could be supplied without any production from primary sources. Current projections indicate that by the year 1985, domestic production will exceed domestic demand by 1.5 million long tons. For this reason, various industry, government, and university groups have initiated research efforts to develop new uses for sulfur.

Sulfur's unique properties permit it to be utilized in construction materials either as a structuring agent, in which it plays the role of the aggregate, or as a binder to hold the materials together, or both. As a result, there has been an increase in research activities to use this versatile element in construction materials.

Utilization in construction offers the most practical approach to new, large-scale uses for sulfur. Sulfur can be used as a direct substitute for asphaltic (4-5) and portland cement (3) and for mineral aggregates (8-9). There has also been development of sulfur foams (1, 6), mortars (2), spray coatings (7) and surface-bonding materials (7).

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UTILIZING SMELTER SLAGS AT WHITE PINE COPPER DIVISION

by

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and W. M. Vlasak[3]

The White Pine Copper Division has been utilizing the discarded reverberatory furnace slag from its smelter in a variety of ways over the past 6 years. The smelter started operation in 1955 and by 1974 had produced over 2 million tons of slag. The long-term average composition of our raw reverberatory furnace slag is given in table 1. However, this average composition is misleading as it is known that the dump contains appreciable tonnages of slag which deviate significantly from the long-term average, particularly with respect to copper content. Copper losses in the slag occur for many reasons:

1. Both the molten copper matte (Cu-Fe sulfides) formed in the smelting process and the copper contained in the converter slag returned to the reverberatory furnace form small droplets which must settle through the slag to collect in the heavier matte pool under the slag layer. The White Pine reverberatory furnace slag is very viscous due to the high SiO_2-FeO ratio, and the smallest copper-bearing droplets become entrained in the slag and are discarded with the slag before they can settle out.

2. If small amounts of nickel get into our final refined copper, it will not meet the guaranteed 100 pct electrical conductivity. When excessive nickel contaminant gets into the smelter circuit, special fire-refining techniques are used to keep the copper clean. These special techniques result in high-copper converter slags being reintroduced into the reverberatory furnace, which exaggerates the losses outlined in 1 above.

3. Toward the end of any furnace campaign, the furnace bottom builds up randomly forming dams, trapping small pockets of liquid matte. It then becomes difficult to get a good slag skim without accidentally taking some of the matte.

4. There is a strong correlation between copper slag losses and the resmelting of plant secondaries (foul slag, ladle shells, cleanup, etc.). About 4 pct of the reverberatory furnace charge is normally secondary materials, but there are periods when excess furnace capacity is available and is used to reduce the inventory of secondaries. A definite increase in slag copper assays can be seen when secondaries form as much as 6 pct of the furnace charge.

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TABLE 1. - Average composition of White Pine reverberatory slag

Composition	Pct	Composition	Pct
Cu	1.35	CaO	20
SiO_2	42	MgO	3
Al_2O_3	12	K_2O	2
FeO	16	Na_2O	2

The very first exploratory studies on copper recovery from the reverberatory slag were done in 1967 at Michigan Technological University using crushing, grinding, and froth flotation. After receiving their results and noting the required fine grind, high energy consumption, and abrasive nature of the slag, the White Pine Metallurgical Research Department decided to try gravity concentration before continuing in the direction of froth flotation copper recovery. Metallurgical evaluation in the laboratory and pilot plant testing in 1968-69 determined that enough copper could be recovered from the reverberatory furnace slag to justify investment in a heavy-media plant.

Construction of the heavy-media plant began in late 1970 and was completed in May 1971. It was designed for seasonal operation, generally April through November. Because of plant startup problems, an industrywide strike, and modifications to the circuit, the plant did not start full operation until April 1972. The heavy-media plant operated seasonally in 1972, 1973, and 1974, treating 1.99 million tons of reverberatory slag to recover 10 million pounds of copper.

In addition to producing a heavy-media copper concentrate for the smelter, the plant made a 1-inch by 4-mesh tailing having approximately 3.0 specific gravity (3.0 float), a 1-inch by 4-mesh product having approximately 3.4 specific gravity (3.4 float), and a 4-mesh by 0 jig tailings; about 1 pct of the plant's feed tonnage reported as minus 100-mesh slime tails.

The 3.0 float and jig tails made an excellent aggregate for a variety of construction purposes including roadbase, drain fields, railroad ballast, concrete, and blacktop roads.

The 3.4 float middling material assays 1.34 pct copper, and this was stockpiled for possible future treatment to recover the contained copper. Laboratory grinding and flotation studies and short test runs in the White Pine concentrator demonstrated that the copper in the 3.4 float could be profitably recovered by blending the 3.4 float with the mine ore for conventional milling and froth flotation. This method has been practiced for the last 2 years with copper sales dictating the daily treatment rate (up to 3,000 short tons per day of 3.4 float into the concentrator). Copper can also be recovered in this manner from jig tails and raw reverberatory slag.

White Pine's recent slag utilization efforts have taken off in a new direction. For the past 1½ years, sized dump slag has been sold to mineral wool insulation manufacturers at rates up to 1,000 tons per week. The reverberatory dump slag is first sized at minus 5 plus 1½ inches and then shipped by rail to the customers. The slag is mixed by the manufacturer with other materials to adjust the overall composition and melted with coke in a cupola furnace. The molten stream issuing from the furnace is spun into mineral wool to be used as insulation.

UTILIZING WASTE RETORTED OIL SHALE FOR HIGHWAY CONSTRUCTION

by

D. Y. Lee[1] and C. A. Carradus[2]

To meet the future energy demand, in view of the threat imposed by the shortage of petroleum and the certainty of its eventual depletion, the United States has expended considerable effort developing oil shale technology in recent years.

Although serious emphasis has been given to the in situ retorting of oil shale, major developmental activity has been directed mainly toward the mining-retorting approach to shale oil production, near the oil shale deposits of the Green River Formation in Colorado, Utah, and Wyoming.

A major and immediate problem in deriving energy from shale oil, aside from costs, technology, and material and manpower, is the disposal of waste (spent shale). The spent shale will be 80 to 85 pct of the raw shale in weight and will occupy a volume up to 50 pct greater than the shale before oil is extracted from it (1). Because of the large increase in bulk volume of the solid residue, the mine cannot accommodate all of the waste, and a significant portion will have to be disposed of aboveground.

Useful deposits of oil shale in the Green River Formation alone are estimated to contain about 2 trillion barrels of crude oil equivalence (5). Extracting this would result in an extraordinarily large volume of waste. For example, the production of 100,000 barrels of oil will result in about 150,000 tons of shale residue. Based on the estimated, slightly compacted density of the shale residue of 90 pounds per cubic foot, complete extraction of the 2 trillion barrels of oil would result in a waste pile of about 1,400 million acre-feet. While attention and study are being given to processed shale revegetation, development of stable dumps, and prevention of excessive blowing of dust, the most desirable solution of the disposal problem is in the form of waste utilization. There is the possibility of using the shale residue from retorting plants as a road construction material, specifically for use as fill material, as stabilized base and subbase, and as aggregate in both portland cement (3-4) and asphalt cement concrete (2).

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UTILIZING SPENT OIL SHALE IN PREPARING GLASS FIBER AND GLASS CERAMICS

by

T. Horiuchi,[1] T. Mizuno,[1] C. H. Chung,[1] and J. D. Mackenzie[1]

Oil shale deposits in the United States exist in at least 30 States (5). The largest and richest oil shale deposits in Colorado, Utah, and Wyoming are well known (1, 3-4).

The average oil in Wyoming contains about 86 pct inorganic solids and 14 pct organic materials with practically no absorbed water (2). This type of shale will yield approximately 25 gallons of oil per ton.

After the oil has been extracted, the disposal of the inorganic residue becomes a problem. Such spent oil shales are easily meltable and can be formed into glass without the addition of other raw materials to the batch (6). The glass is easily converted to a fine-grained glass ceramic of superior properties (7).

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ABUNDANCE AND RECOVERY OF SPHALERITE AND FINE COAL FROM MINE WASTES IN ILLINOIS

by

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Resource investigations of zinc in sphalerite-bearing coals in west-central Illinois show that the in situ zinc content of three coals mined ranges from 0.05 to 0.09 pct. The highest concentrations of zinc, up to 0.5 pct, occur locally in disturbed areas of the coalbeds characterized by faults, slips, fractures, and clastic intrusions. Undisturbed portions of the coal usually contain less than 0.005 pct zinc.

Zinc is present in the coal as a sulfide mineral, sphalerite (ZnS with up to 1 pct cadmium). Sphalerite occurs as fillings in fractures, cleats, and faults, and as crystal aggregates in clastic dikes which intrude the coals. The occurrence of sphalerite in coals and the relative ease with which the sphalerite can be reduced in the coal by specific gravity techniques is discussed by Hatch, Gluskoter, and Lindhal (1), who speculated that recoverable quantities of sphalerite could be present in some existing coal refuse deposits.

The west-central Illinois mining district (Fulton, Knox, Peoria, and Stark Counties) has an estimated coal resource of 7,500 million tons (3) occurring in three seams: the Colchester (No. 2), Springfield (No. 5), and Herrin (No. 6). With a zinc concentration from 0.05 to 0.09 pct, the coals in this area contain several million tons of zinc, an amount equal to that of some zinc mining districts.

The annual raw coal production from this area is about 10 million tons. This raw coal is crushed, washed, and screened in preparation processes. The coarse-grained refuse is hauled to gob piles, and the fine-grained refuse is slurried and discharged into impoundments. A survey of surface-mined land in Illinois (2) lists 1,018 acres of uncovered slurry deposits and 858 acres of uncovered gob deposits in the west-central Illinois district.

Random sampling of slurry and gob deposits from different mines in the area shows the concentration of sphalerite in refuse (tables 1 and 2). The zinc content of these gob samples ranges from 0.001 to 0.6 pct, and that of slurry samples is 0.001 to 2.3 pct. Table 3 shows the zinc content of washed coal to range from 0.007 to 0.025 pct.

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TABLE 1. - Zinc and cadmium in grab samples of coarse-grained refuse (gob)

Coal	Sample type	Zinc, pct	Cadmium, pct	Coal	Sample type	Zinc, pct	Cadmium, pct
5	Gob pile.........	0.330	0.0031	5 and 6	Preparation plant	0.230	0.0021
6	.......do........	.006	.0001	5 and 6	.......do........	.050	.0004
6	.......do........	.090	.0007	5	.......do........	.220	.0032
5 and 6	.......do........	.520	.0006	5	.......do........	.150	.0018
5 and 6	Preparation plant	.440	.0002	5	.......do........	.100	.0011
5 and 6	.......do........	.640	.0007	5	.......do........	.010	.0002

TABLE 2. - Zinc and cadmium in grab samples of fine-grained refuse deposits (slurry wastes)

Coals	Zinc, pct	Cadmium, pct	Coals	Zinc, pct	Cadmium, pct
6	0.130	0.0015	5	0.010	0.0001
6	.270	.0025	2	1.750	.0190
5	.650	.0071	2	2.360	.0280
5	.320	.0038	2	.110	.0013
5	.410	.0048			

TABLE 3. - Zinc and cadmium in washed coal samples

Coal	Sample description	Zinc, pct	Cadmium, pct
5 and 6	Coal (minus 6 plus 3 in)....	0.010	0.0001
5 and 6	Coal (minus 3 plus 1-1/4 in)	.020	.0001
5 and 6	Coal (minus 1-1/4 plus 3/4 in).	.007	.0001
5	Coal (1-1/2 in)............	.025	.0005

The Humphreys spiral concentrator produced first-stage coal and heavy mineral concentrates from the refuse fan. There was a 324-pct average effective increase in the zinc content of the heavy mineral concentrate. The total carbon content in the coal concentrate increased an average of 72 pct. The best coal concentrate contained 97 pct coal and only 3 pct discrete mineral particles. Chemical analyses showed this coal concentrate to contain 2.6 pct total sulfur and 9 pct ash. Secondary and tertiary beneficiation stages could be expected to further improve the quality of these concentrates.

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UTILIZING BAYER PROCESS MUDS: PROBLEMS AND POSSIBILITIES

by

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Aluminum metal and aluminum oxide products are made almost entirely from bauxite, a naturally occurring mixture of hydrated aluminum oxide minerals. Silica, iron oxide, and titania are generally present in various amounts, and other elements occur in trace elements. Typical analyses of different bauxites are given in table 1.

TABLE 1. - Typical analyses of various bauxites[1]

Constituents	Weight-percent			
	Jamaican	Surinam	Arkansas	Guyana
Al_2O_3, total	49.2	55.0	48.7	58.6
SiO_2	.7	3.8	15.3	4.9
Fe_2O_3	19.3	7.0	6.5	4.1
TiO_2	2.5	2.4	2.1	2.5
F	NA	NA	.2	.02
P_2O_5	.4	.06	NA	NA
V_2O_5	.03	.04	NA	NA
H_2O, combined	26.5	31.2	25.8	29.6
Al_2O_3, trihydrate	44.4	50.0	34.1	52.7
Al_2O_3, monohydrate	2.8	.2	14.6	5.9

NA Not available.
[1]Analyses provided by the operating company.

Alumina (Al_2O_3) is extracted from bauxite by the Bayer process. For bauxite containing high amounts of reactive silica, a combination process is used that incorporates a lime sinter step with the Bayer process. The major process waste producing alumina is the leach residue from the caustic digestion of bauxite. This waste material can be claylike in nature and is generally referred to as "red mud" because the iron oxide content usually imparts a red color to the waste. Residues from processing the bauxite by the combination process are called "brown muds."

This waste mud is pumped from the processing plants as a slurry containing about 20 pct solids and is impounded in mud lakes. Approximately 10 million tons of mud waste are generated annually in the United States (table 2).

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TABLE 2. - List of domestic bauxite refineries

Company	Plant location	Type of bauxite used	Approximate plant capacity,[1] metric tons of alumina per year	Approximate waste (mud) produced,[1] metric tons per year
Aluminum Co. of America (Alcoa).	Mobile, Ala..........	Surinam-African.......	1,500,000	450,000
	Point Comfort, Tex...	Caribbean-Surinam-African-Australian.	1,100,000	1,100,000
........Do.........	Bauxite, Ark.........	Domestic (Arkansas)...	225,000	450,000
Kaiser Aluminum and Chemical Corp.	Baton Rouge, La......	Jamaican..............	1,000,000	1,000,000
	Gramercy, La.........	.........do...........	800,000	800,000
Reynolds Metals Co.	Corpus Christi, Tex..	Jamaican-Haiti........	1,300,000	1,300,000
	Hurricane Creek, Ark.	Domestic (Arkansas)...	755,000	1,510,000
Ormet Corp.........	Burnside, La.........	Surinam...............	560,000	168,000
Martin-Marietta Aluminum Co.	St. Croix, Virgin Islands.	Weippa-Guyana-Surinam-Kassa-Boke (Guinea).	325,000	NA

NA Not available.
[1]Information provided by individual operating company.

From the standpoint of effluent control, impoundment is not an ideal solution to the mud waste disposal problem. Mud lakes require a significant amount of land because the settling rate of solids is generally very slow. The land area committed to impoundment at each plant site is about 2,000 to 3,000 acres. The dikes of a mud lake must be maintained, and there is always risk of a break and spill of the mud into a nearby stream or waterway. Certain muds are almost thixotropic in character, and even the old, apparently dried mud lakes cannot support heavy equipment or construction. The problems, of course, vary with the source of bauxite and the location of the process plants.

The use of the muds for recovery of metals has emphasized the extraction of iron. Recovery of titania and additional alumina has been of some interest also. Some attention has been given to the technology of extraction of the higher unit value metals niobium, gallium, and vanadium. However, commercial recovery has not been tried because of the very low concentration of these elements.

Several processes have been developed to recover iron from the red mud residues. One method is the carbon-lime-soda sinter processes which can be applied to ore or to the red mud (1, 3). In this process, the iron is reduced and recovered by magnetic separation from the waste residues after the alumina has been leached.

Direct electric arc smelting of the red mud has been proposed for recovery of iron from high-iron-content bauxites (5). In this case, pig iron can be produced with up to 98 pct recovery of the iron content of the bauxite. The slag from the smelting can also be further treated to recover up to 84 pct of the alumina lost by the Bayer process. This particular process was advocated as being both technically and economically feasible based on pilot-plant-scale development work. The economics assume that the pig iron or steel would be produced near the bauxite-refining plant to take advantage of low-cost iron units. The U.S. iron and steel industry has not taken steps to commercialize the process. Economics require a low-cost means to completely dewater the mud. Moreover, trace elements present in the muds, for example, phosphorus, are recognized to have a very significant and adverse effect on steel quality. Numerous other processes for iron recovery are described in the literature (7).

Alumina and titania can be recovered from the mud. If the mud is smelted for iron recovery, the slag from the smelting operation can be leached with sodium carbonate solution to recover most of the alumina. Titania can be recovered from the residue by leaching. The extraction of titanium from the red mud is technically feasible, but the complicated processing makes this too costly to compete with recovery from natural titanium ores such as ilmenite or rutile.

Other rare metals such as gallium, vanadium, and scandium can be recovered from the red mud residues or at various stages in the Bayer process. Gallium recovery from the caustic aluminate liquors (6) is economical. Several studies have also been conducted on vanadium recovery. In one method, a vanadium slag is separated in the production of pig iron (2). In another

method, liquid-liquid extraction by amines is used on the leach liquors from the Bayer process to recover vanadium (4).

The scope of interest in the application of the Bayer muds for ceramic products is indicated in table 3. Cement, building blocks, or brick and to a lesser extent lightweight aggregate are patented large-tonnage applications that could help alleviate the disposal problem. Treatment would be required in all cases. Generally some dewatering would be necessary to make red mud brick and lightweight aggregate. Acid washing would be required for use of the mud as a cement or rubber filler. Complete drying and powder preparation would be needed for other filler applications.

TABLE 3. - Possible ceramic uses for red muds reported in the technical literature

Field of application	Number of publications
Cement material	22
Construction block material	16
Lightweight aggregate material	10
Plastic and resin filler	9
Pigment	6
Miscellaneous materials recovery	6
Caustic recovery	5
Catalyst material	4
Fertilizer material	4
Coating material	3
Insecticide material	2
Refractory cement material	2
Road, pavement, soil stabilization material	2
Metal surface treatment material	1
Sewage treatment material	1
Glass material	1
Insulation material	1
Coke additive	1
Total	96

Despite this extensive work worldwide to develop means to utilize Bayer process muds, the technology is not available that would allow economic processing of muds into products having sufficient existing markets to reduce the present need for impoundment.

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CONSTRUCTION INDUSTRY EFFORTS TO UTILIZE MINING AND METALLURGICAL WASTES

by

R. J. Collins[1]

Mining and metallurgical wastes represent one of the largest sources of solid waste produced in our society. Each year nearly 2 billion tons of solid wastes are generated by the mining and mineral processing industries. Many of these materials, because they are essentially rocklike or earthen, have potential for use in various forms of construction. Although certain of these wastes have been used at one time or another for construction purposes, they are generally avoided in favor of conventional materials. Consequently, over the years hugh stockpiles of mining and metallurgical wastes have accumulated in many areas.

Because of their similarity to acceptable construction materials and the large quantities that are involved, mining and metallurgical wastes should be seriously considered as alternative construction material sources in areas of the United States where conditions warrant such use. To assess the potential of mining and metallurgical wastes for use in some form of construction, it is necessary to be aware of the types, locations, available quantities, and general nature of these materials.

The Federal Highway Administration sponsored a recently completed research study aimed at determining the availability of mining wastes and their physical and chemical characteristics. Besides developing this much-needed information, the study determined the extent to which these waste materials have been utilized in highway and other types of construction work (1). Much of the information reported herein was obtained as a result of this study.

Some understanding of the nature of mining and mineral processing wastes is needed prior to discussing the technical, environmental, and economic aspects of their use. It is, therefore, essential to classify and describe the various types of waste materials resulting from the mining, milling, and refining of minerals and ores. These wastes are classified in the following general categories:

1. Waste rock
2. Mill tailings
3. Coal refuse
4. Metallurgical slags

The estimated quantities of waste rock, mill tailings, coal refuse, and slags produced annually by the mining and mineral processing industries in the United States are shown in table 1. Also noted in this table are the estimated quantities of mineral processing wastes that have accumulated from past years of mining activity.

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TABLE 1. - Inventory of mining and metallurgical waste production and accumulation

(Million tons per year)

Mining industry	Waste rock[1]	Mill tailings	Smelter slag	Estimated total waste accumulation	Principal areas of occurrence
Metals:					
Alumina	9.2	[2]6.1	-	50.0	Texas, Louisiana, Arkansas.
Copper	688.0	260.0	4.0	8,500.0	Arizona, Utah, Montana, Michigan, Tennessee, New Mexico, Nevada.
Gold	16.0	6.0	-	500.0	California, South Dakota, Nevada.
Iron ore	30.0	30.0	-	800.0	Minnesota, Michigan, Missouri, California, Pennsylvania.
Lead	.6	9.0	.5	200.0	Missouri, Colorado, Kansas, Oklahoma.
Nickel	-	-	.8	15.0	Southwestern Oregon.
Silver	.2	.7	-	Uncertain	Colorado, Idaho, Nevada.
Taconite	110.0	120.0	-	4,000.0	Northeastern Minnesota.
Uranium	172.0	6.5	-	125.0	Wyoming, Utah, Colorado, New Mexico.
Zinc	1.0	7.9	.4	200.0	Colorado, Idaho, Pennsylvania, Tennessee.
Nonmetals:					
Asbestos	.7	2.0	-	15.0	California, Vermont, Arizona, North Carolina.
Barite	2.1	3.4	-	25.0	Nevada, Missouri, Arkansas.
Feldspar	.2	.9	-	Uncertain	North Carolina, California, Connecticut.
Fluorspar	.1	.4	-	Uncertain	Illinois, Colorado.
Gypsum	15.7	.3	-	Uncertain	Michigan, Texas, Iowa, California, Oklahoma.
Phosphate	254.0	[3]60.0	4.0	[4]1,000.0	Central Florida, Idaho, Tennessee.
Coal refuse:					
Anthracite	-	[5].8	-	1,000.0	Northeastern Pennsylvania.
Bituminous	-	[5]100.0	-	2,500.0	Kentucky, West Virginia, Pennsylvania, Illinois, Ohio, Virginia, Indiana, Alabama.
Iron and steel slag:					
Blast furnace	-	-	30.0	Uncertain	Pennsylvania, Ohio, Illinois, Indiana, Michigan, Alabama, Maryland, California.
Steel furnace	-	-	12.0	Uncertain	Do.
Total	1,299.8	614.0	51.7		

[1]Includes waste rock and overburden in some operations.
[2]Includes estimated 6 million tons of alumina mud.
[3]Includes both phosphate slimes and phosphogypsum.
[4]Includes estimated 150 million tons of phosphogypsum.
[5]Includes coarse and fine preparation plant refuse.

NOTE.--The above totals do not include an estimated 75 million tons of solid wastes (including dusts) which are generated annually by crushed stone, building stone, and slate quarries and by sand and gravel pit operations.

One means of assessing the suitability of waste rock in construction is to determine the extent of use and performance record of various waste rock sources for this purpose. It is also important to remember that many waste rock materials have been successfully used by mining companies for years in the construction of embankments and haul roads on mining property.

The huge quantities of mining and metallurgical wastes that have been accumulated are currently being produced in many areas throughout the United States. Many of these materials have been successfully used in some form of highway construction or are potentially suitable for this purpose. Certain materials, such as iron ore waste rock, coarse taconite tailings, phosphate slag, and properly aged steel slag, possess unique properties and are actually superior to most conventional construction materials. Other sources of mineral wastes, such as coarse tailings and coal refuse, are quite acceptable for some construction uses, provided they are properly prepared and applied.

A greater awareness and recognition is needed of the existence and usefulness of many of these byproducts. Sizable quantities of these materials are often available near areas where the supply of conventional aggregates is diminishing. A large number of mining and metallurgical wastes are well suited to construction use. Their utilization would in many cases improve the quality of facilities in which they were applied, reduce costs, and conserve badly needed natural resources. In addition, the potential for savings in energy by substitution of certain byproducts is an important consideration which further recommends their utilization.

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IRON RECOVERY AND GLASS FIBER PRODUCTION FROM COPPER SLAG

by

C. H. Chung,[1] T. Mizuno,[1] and J. D. Mackenzie[2]

The present total capacity in the United States for processing copper from porphyry copper ores is estimated to be 1,592,000 tons of ores annually (5). The maximum amount of slag produced, assuming full production, is 849,000 tons per year (1). This presents a serious environmental problem. On the other hand, this slag could be considered as a raw material for ceramic products. Most of the efforts to solve this problem were based on the conversion of the copper slag into glass ceramic (2-4). However, precipitation of magnetite (Fe_3O_4), maghemite (γ-Fe_2O_3), and hendenbergite ($CaO \cdot FeO \cdot 2SiO_2$) occurred during heat treatment of the glass, and controllable crystallization was difficult (3). The research was directed to converting the slag into glass fiber and also to recovering the iron via a feasible process.

The total iron content in the copper slag corresponds to the equivalent of ~47 pct Fe_2O_3. Most of this iron exists in the form of fine maghemite particles embedded in the slag. The extraction of this iron oxide by conventional mechanical and magnetic separation processes is difficult. The manufacture of glass from the copper slag also requires a melting temperature in excess of 1,500° C because of the low alkali and alkaline earth contents. The energy necessary in melting is therefore considerable. The high iron content in the slag also created problems in the corrosion of refractories. A typical analysis of a copper slag is shown in table 1; the Fe_2O_3 content is 47.1 pct.

The chemical compositions of the glass and the iron produced from copper slag are shown in tables 1 and 2, respectively. The iron metal was found to contain 1.6 pct Mo and 0.78 pct Cu. Presumably because the iron was formed at a temperature below 1,535° C, the samples were fairly porous. The bulk density was 6.88 grams per cubic centimeter, compared with the theoretical density for pure iron of 7.86 grams per cubic centimeter.

The glass was dark brown in color because of the high content of iron oxide. Some physical and chemical properties measured are shown in table 3 in comparison with those of common window glass. The fibers were light brown in color. Continuous fibers were readily made and showed no surface crystallization.

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TABLE 1. - Composition of copper slag and glass, wt-pct

Compound	Copper slag	Glass
SiO_2	34.3	49.0
Al_2O_3	5.2	14.0
Fe_2O_3	47.1	17.0
CaO	9.1	14.0
MgO	1.5	1.5
TiO_2	.5	.8
CuO	.3	.1
ZnO	.7	.6

TABLE 2. - Composition of metal from copper slag, wt-pct

Fe	97.5
Mo	1.6
Cu	.78
Co	.057
Sn	.016
Si	.013
Ni	.007
C	.012

TABLE 3. - Properties of glass from copper slag compared with window glass

	Copper slag glass	Window glass
Glass transition temperature ° C	623	530
Thermal expansion coefficiency	61×10^{-7}	90×10^{-7}
Alkali resistance mg/cm^2	0.22	0.25
Hardness (Knoop) kg/mm^2	823	443
Density g/cm^3	3.41	2.50

Based on the present preliminary work, it appears that the continuous production of iron and glass fibers from copper slag is feasible. A schematic drawing of a possible continuous melting tank is shown in figure 1. Dense zircon refractory can be used for the inside wall of the tank. A movable dense zircon plug in section A allows the metallic iron to be withdrawn from the melt periodically. The batch can be charged from the top of zone A. Zone B is the homogenization furnace where the temperature can be kept at 1,350° C or higher. Zone C should be maintained at 950° C if fiber is made by the updraw method, or somewhat higher if glass wool is made by downdraw.

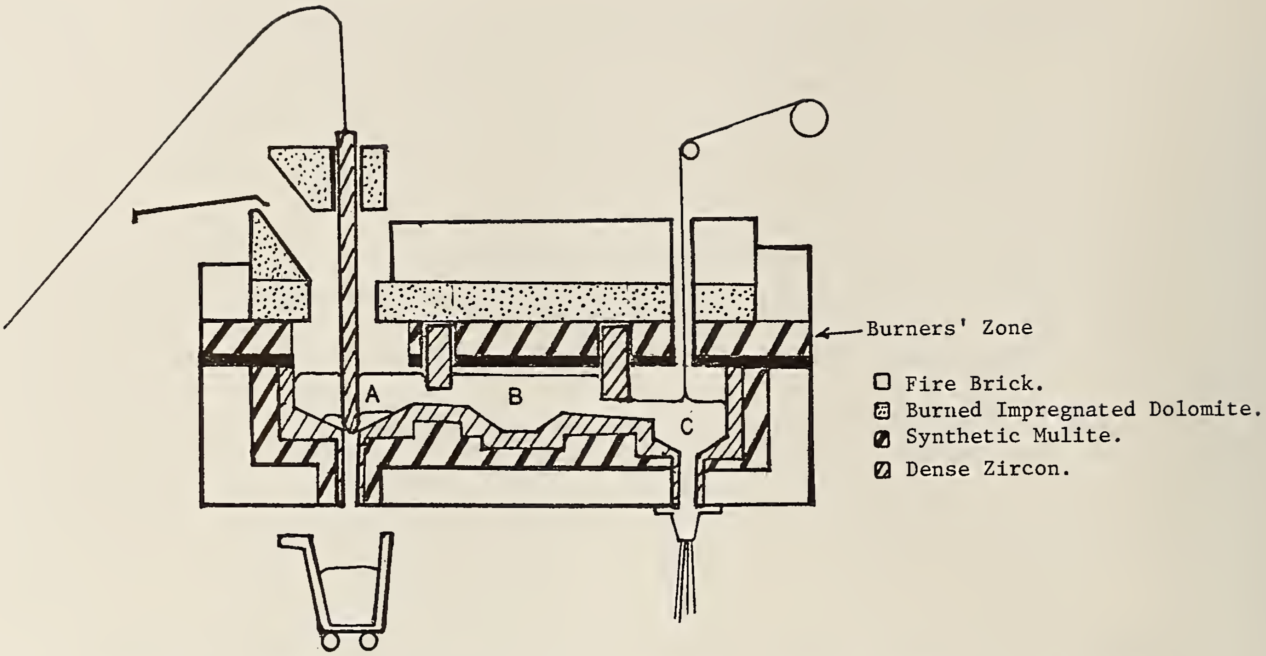

FIGURE 1. - Proposed tank design for continuous production of iron and glass fibers from copper slag.

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MUNICIPAL REFUSE

RESOURCE RECOVERY FOR MUNICIPAL SOLID WASTE DISPOSAL--AN OVERVIEW

by

P. J. Cambourelis[1]

Archeological information on the nature of man's earliest societies comes primarily from examination of discarded materials left on what was then open countryside. In a nomadic society, populating the surface of the earth very sparsely, there was no reason for concern. Even as man "settled down" and his numbers increased, the problem of waste disposal continued to be insignificant. Man, of necessity, lived a frugal existence, repairing and reusing articles as often as possible. What little waste materialized, because population densities were still quite low, was moved out of man's way with little inconvenience.

The industrial reveoltion changed all this. Society began large-scale use of materials for increasing quantities of mass-produced goods. The system required population to be concentrated around the centers of production. The overall population trend in the United States, together with the trend in urbanization, is shown in figure 1. The more affluent segments of society, including developed nations such as the United States, used manufactured goods for shorter and shorter periods. The consumer society recognized and accepted concepts of planned obsolescence and nonreusable goods and containers.

Energy consumption followed suit. For a while it was cheaper to leave electric lights on continuously in large office buildings than to turn them off during off hours. In the United States mass transportation gave way to automobiles within two generations. Commuting to work by auto became normal. In the very recent past, commuting usually involved only one passenger-driver per 3,500-pound vehicle.

The trend in energy consumption began to change in the 1960's when we began to see strange-looking but relatively light, low-fuel-using Volkswagen Beetles on our highways. The 1960's also spawned a reexamination of some of the effects of the consumer society on quality of life and on what had become a rapidly degrading environment. The U.S. Environmental Protection Agency (EPA) emerged during this time, originally as an arm of the Housing and Urban Development Agency (HUD) and finally on its own as a Federal agency reporting to the President.

Both air and ground pollution were recognized as serious problems. Even the oceans, covering 70 pct of the Earth's surface, were affected. For example, surprisingly high heavy-metal contamination was found in certain fish, and dangerous trace quantities of residual, chlorinated hydrocarbons were detected in birds. Political-legislative action followed the increasing

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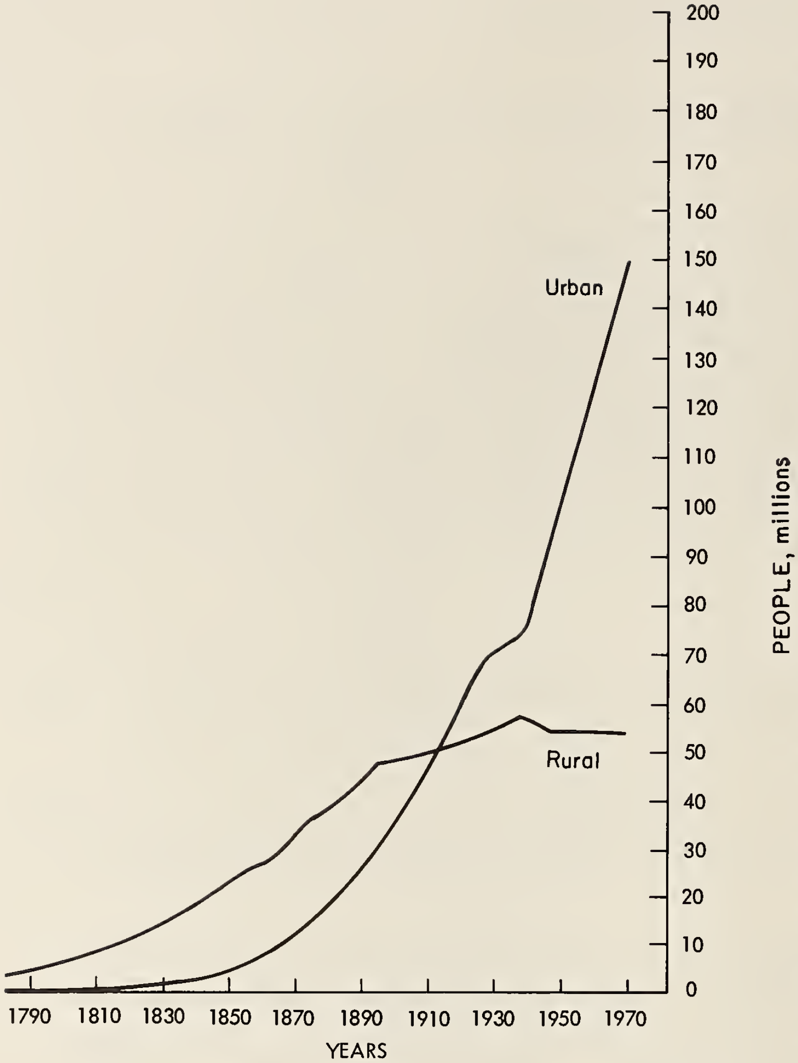

FIGURE 1. - Urban and rural population. (1976 U.S. Bureau of Census Statistical Abstract.)

social awareness of serious environmental problems developing.

The U.S. Bureau of Mines pioneered with two pilot plants extracting fuel, metals, and glass from municipal waste.

EPA was established and initiated large-scale resource recovery demonstration programs; it now develops and monitors environmental quality standards.

The Clean Air Act had a very drastic effect on incineration of wastes and open burning dumps. Required additions of sophisticated, electrostatic precipitation equipment to refractory-lined incinerators often cost significantly more than the incinerators themselves had cost originally. Water quality and pollution control legislation resulted in the emergence of proposed guidelines for control of landfill practices. Effluent discharge limits and harmful leachate controls needed to protect water supplies are now emerging. There is little doubt that the Resource Conservation and Recovery Act of 1976 will result, eventually, in strict landfill requirements.

The type of resource recovery system selected is dependent primarily on net disposal charge. Unique local political, market, and geographic considerations also significantly affect selection. Political considerations usually have critical impact on schedule, financing, and contractual requirements.

The resource recovery systems referred to in table 1 provide ample evidence of a broad range of technical options available for consideration.

Financing and contractual options also provide a wide range of alternatives for consideration. Since detailed discussion of these considerations is beyond the scope of this paper, they are only mentioned briefly.

TABLE 1. - Current resource recovery projects[1]

Major system category by type of energy recovery	Number of plants	Total capacity, tons per day	Total capital, million dollars	Average capital cost, thousand dollars per ton of daily capacity
Direct combustion	2	1,560	76.5	49,000
Refuse-derived fuel for dedicated boiler	2	3,500	121.0	34,600
Refuse-derived fuel for sale	8	8,450	138.0	16,300
Pyrolysis	3	1,400	59.5	42,500
Pulverized refuse-derived fuel	3	4,000	90.0	22,500
Hydropulping	3	5,150	158.2	30,700
Bioprocessing	1	100	3.1	31,000
Total	22	24,160	646.3	$26,800

Major system category by type of energy recovery	Percent of market (capacity)			Range of capital cost, thousand dollars per ton of daily capacity	
	All	Solid fuel mf'd	Dry process only	Minimum	Maximum
Direct combustion	6.5			41.6	73.6
Refuse-derived fuel for dedicated boiler	14.5	•	•	30.0	46.0
Refuse-derived fuel for sale	35.0	•	•	4.2	25.2
Pyrolysis	5.8			30.0	75.0
Pulverized refuse-derived fuels	16.5	•	•	10.0	29.4
Hydropulping	21.3	•		21.3	38.2
Bioprocessing	0.4			31.0	31.0
Total	100.0	87.3	66	4.2	75.0

• Indicates column head applies for listed item.

[1] Included are operational systems and systems now in construction or final design and fully committed.

Source: National Center for Resource Recovery, October 1977.

Funding sources include national and State grants, as well as State, county, or municipal general obligation bonds. However, revenue bond financing appears to have emerged as the dominant approach even though it may lead to higher disposal charges.

Conventional contractual arrangements--that is, use of architectural and engineering consultants for design and to prepare bid packages as required for competitive bidding for hardware and construction--can be expected for selected situations. However, the trend to revenue bond financing appears to have reinforced an existing need for overall system management with responsibility extending into shakedown and long-term operational phases as well. Contractual forms are tending to take on many of the characteristics of turnkey arrangements. Full-service contracts are being considered in a number of situations.

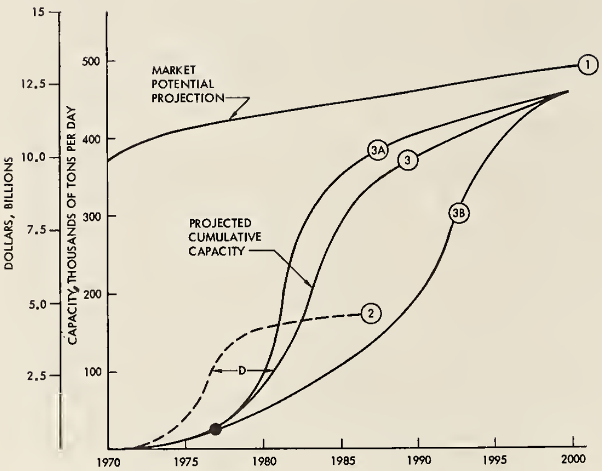

FIGURE 2. - Supply and demand curves.

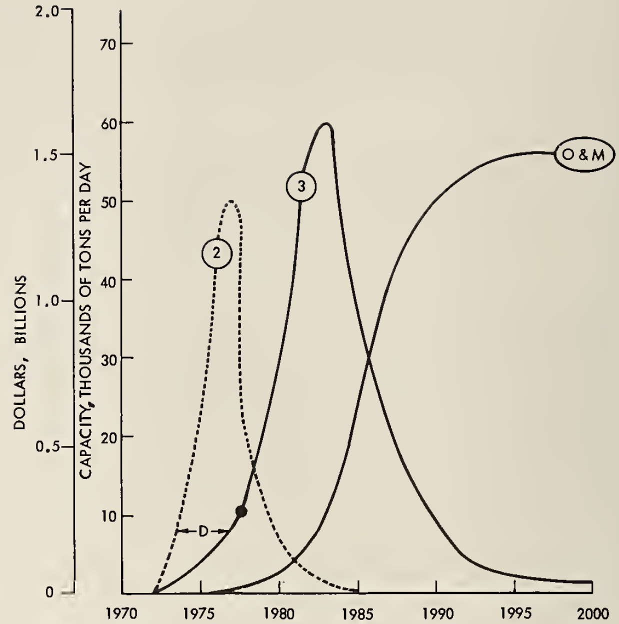

FIGURE 3. - Annualized expenditures for capital and operating cost.

The institutional and political complexities referred to above significantly affect the financing and contractural methods used and are believed by many to cause much of the 5- and 10-year project delay shown graphically in figures 2 and 3.

In figure 2 the maximum processing capacity potential represented by Standard Metropolitan Statistical Areas (SMSA's) of 100,000 people or larger is shown. The dollar scale on the left side is based on the $26,800 average cost per ton of daily capacity indicated above. Curve 2 is based on a survey conducted by Raytheon Service Co. in 1975-76 in which over 150 out of 157 SMSA's of 250,000 people or more were contacted. At that time over half of those contacted indicated plans to initiate resource recovery systems. Curves 3A and 3B outline a zone within which the path of resource recovery capacity is likely to move. Curve 3 shows the early, slow development of capacity that has occurred to the present. The dot on curve 3 represents the 24,000 tons of capacity represented by current projects. Figure 3 annualizes the cumulative data shown in figure 2. Also shown are the projected annual operating and maintenance costs that would result as the system developed in accordance with the frequency shown on curve 3 becomes operational. Of particular interest is the observation that sustained annual O&M expenditure levels of about the same order of magnitude as expected for peak annual expenditures for system acquisition can be anticipated.

It will be interesting to observe development of the resource recovery system business over the next 5 to 10 years, as operating experience accumulates for the several system types referred to above, under varying funding and contractual arrangements.

ALBANY-NEW YORK SOLID WASTE ENERGY RECOVERY SYSTEM (ANSWERS): CITY-STATE PARTNERSHIP IN SOLID WASTE ENERGY RECOVERY RETURNS PROFIT TO BOTH

by

P. F. Mahoney[1]

In October 1976, the City of Albany and the State of New York signed a unique 20-year agreement which will solve the problems of solid waste disposal for the city, and stabilize the rising costs of energy for the State office building complex. Under the agreement, the city will process municipal solid waste to produce a fuel to be purchased by the New York State Office of General Services (OGS), and OGS will construct two new refuse-fired boilers to generate steam to heat and cool the Empire State Plaza and other major State buildings located in downtown Albany. The refuse-derived fuel (RDF) product will be sold to the State at a 20-pct cost savings over the market price for No. 6 fuel oil, the current fuel being used. The contract represents an exceptional declaration of cooperation between municipal and State governments on a project that will result in significant savings for all parties.

When the City of Albany first considered the concept of recovering energy and materials from solid waste as an alternative to landfilling, the following design objectives were established:

1. To provide an environmentally acceptable, economical alternative to landfilling.

2. To economically produce a competitively marketable fuel or energy product.

3. To economically recover all recyclable materials for which there is a market.

4. To design a system which had no environmentally undesirable waste or byproducts.

5. To use only existing or proven technology in the system.

The system, the Albany-New York Solid Waste Energy Recovery System (ANSWERS), is a regional resource recovery program designed to initially process 750 tons per day of municipal solid waste, producing a fuel for steam generation and recovering all recyclable materials. It developed out of an imperative need to find an alternative to sanitary landfilling in the City of Albany. A municipal commitment to preserve the quality of the physical environment and conserve energy together with a fuel customer willing to use a processed refuse fuel to save energy and reduce costs have been the key ingredients in the development of this project. The amount of fuel needed by the State is approximately equivalent to the amount of RDF the city can process on a day-to-day basis. Most sifnificantly, ANSWERS has been designed to be a profitmaking venture, and is, therefore, an economically attractive program for all those concerned.

The project is well under construction, commitments for delivery and purchase of fuel have been signed, bid prices have been within the budget, and startup is scheduled for May 1980.

[1]Managing partner, Smith and Mahoney, Consulting Engineers, Albany, N.Y.

DIRECT INCINERATION OF MUNICIPAL SOLID WASTE VERSUS SEPARATION OF COMBUSTIBLES

by

S. L. Law,[1] B. W. Haynes,[2] and W. J. Campbell[3]

This study was conducted as part of the U.S. Department of the Interior, Bureau of Mines program to develop technology for increasing the Nation's mineral supply through recovery of valuable constituents from currently discarded waste materials. Municipal solid waste (MSW), although presently a major disposal problem, represents a significant potential source of metals, glass, and combustible materials. The technical and economic feasibility of physically separating MSW for metal, glass, and combustible fraction recovery has been successfully demonstrated in the Bureau of Mines 5-ton-per-hour urban refuse pilot plant (5-7).

The combustible fraction is approximately 70 wt-pct of the MSW and is composed of paper, plastics, yard wastes, putrescibles, wood fabric (table 1), and other minor components that are separated from the metals, glass, and other noncombustibles during the operation of the pilot plant. This fraction can be a valuable supplement to coal in the generation of heat and electricity. Evaluation of the combustible fraction as a fuel supplement is an essential part of the research leading to total resource recovery from MSW. Although the combustibles are a valuable source of energy, as demonstrated by a Bureau of Mines evaluation described in BuMines Report of Investigations 8044, some resistance to the application of MSW as a fuel supplement has occurred because of speculation concerning trace metal emissions to the atmosphere when the combustible fraction of MSW is burned together with coal (9). However, the limited data available on combustion of MSW were derived from municipal incinerators where the MSW was not separated into combustible and noncombustible fractions prior to incineration (8, 10).

If the total MSW is burned, as in municipal incinerators, the emitted metals may come from one or both of the two major components of MSW--the combustible fraction (paper, cardboard, plastics, fabrics, etc.) and/or the noncombustible fraction (ferrous metals, nonferrous metals, glass, ceramics, etc.). The purpose of this Bureau of Mines study was to determine if separation of the combustibles from the total MSW will result in lower concentrations in the fuel supplement of elements that are objectionable from environmental considerations. Available data from municipal incinerator studies and from analyses of the combustible fractions of MSW, although not originally intended for source identification, are used to identify elements and sources (table 2).

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[2]Chemist
[3]Supervisory research chemist.
All of the authors are with the Avondale Research Center, Bureau of Mines, Avondale, Md.

TABLE 1. - Composition of typical refuse, dry basis

Product	Pct	Product	Pct
Ferrous metal..................	7.6	Corrugated board...............	3.5
Aluminum.......................	1.1	Paper..........................	51.7
Heavy nonferrous metal.........	.2	Putrescibles...................	4.4
Plastics.......................	5.0	Glass..........................	10.5
Leather and rubber.............	.7	Miscellaneous..................	.9
Fabrics........................	1.8	Fine glass, grit, dirt, and	
Wood...........................	2.6	ceramics.....................	10.0

Source: Reference 7.

TABLE 2. - Elemental input from combustible MSW and output during 1 week's operation of a model municipal incinerator

Element	Quantity, kg			Fraction remaining, pct	
	Input from light combustibles[1]	Input from total combustible MSW[1]	Output in incinerator residues[2]	Not accounted for by light combustibles	Not accounted for by total combustibles
Ag.....	1	2	6	83	67
Al.....	4,700	5,800	5,500	[3]15	-
Ba.....	80	110	120	33	[3]8
Ca.....	2,900	6,300	3,200	[3]9	-
Cd.....	2	6	8	75	[3]25
Co.....	1	2	6	83	67
Cr.....	25	35	60	58	42
Cu.....	80	230	50	-	-
Fe.....	880	1,500	1,500	41	-
Hg.....	.5	1	1	[3]50	-
K......	410	840	720	43	-
Li.....	1	1	2	[3]50	[3]50
Mg.....	640	1,000	1,000	36	-
Mn.....	60	80	230	74	65
Na.....	1,900	2,900	1,500	-	-
Ni.....	7	10	50	86	80
Pb.....	130	210	620	79	66
Sb.....	20	20	20	-	-
Sn.....	10	10	90	89	89
Zn.....	370	500	1,000	63	50

[1]Based on 920 metric tons (dry weight) of MSW per week, 53 pct light combustibles, 70 pct total combustibles, and data in references 1, 2, and 4.

[2]Based on 62 metric tons of fine bottom ash (bulk scrap, cans, bottles, etc., excluded), 20 metric tons of fly ash, 3.8 metric tons of atmospheric particles, and 133,000 liters of recycled water per week (see reference 3).

[3]Could be accounted for by ranges in the original data (1, 4).

Data on metal concentrations in municipal solid waste and in municipal incinerator residues have been examined to distinguish between combustible and noncombustible sources of the metals that may appear in the residues from the combustion of an MSW-derived fuel. Cadmium, chromium, lead, manganese, silver, tin, and zinc apparently come from the noncombustible components of refuse as

well as from the combustibles. The removal of the noncombustible components of municipal solid waste by some recycling operation prior to use of the combustible components for fuel will reduce the concentrations of these seven metals. Also, concentrations of antimony, cobalt, mercury, nickel, and possibly other metals may be reduced by separating the combustibles from the noncombustibles prior to burning. A further reduction of cadmium, copper, and other heavy metals possibly can be realized by not including the heavy combustibles, especially the heavy-gage plastics, in the MSW fuel supplement. The light combustibles from MSW are the refuse-derived fuel source containing the lowest concentrations of trace and minor elements.

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PREPARING DENSIFIED REFUSE-DERIVED FUEL ON A PILOT SCALE

by

H. Alter[1] and J. Arnold[2]

Refuse-derived fuel (RDF) generally refers to the product of the mechanical (or chemical plus mechanical) processing of municipal solid waste (MSW) to produce a specification fuel. For example, the product of shredding and air classification of MSW is one form of RDF.

By densified refuse-derived fuel (d-RDF) is meant the product of the mechanical compaction of some form of RDF to agglomerated pieces which are sufficiently cohesive to sustain storage and handling. The term "densified" is used in the generic sense to include all manner and forms of compaction, such as extrusion or rolling to produce what are commonly called briquets, pellets, cubettes, etc. Generally, d-RDF would be intended as a fuel for some type of stoker boiler.

Probably the first d-RDF was prepared by F. C. Stirrup in 1959. using at first wood chips and shavings and then municipal refuse. The process consisted of shredding, suspension drying to 8 to 10 pct moisture, and extrusion. In 1960, Stirrup reported the preparation and properties of extruded briquets from German and British refuse on scales up to 6 tons per hour. The process consisted of magnetic separation, shredding (using a Novorotor grinder), drying in a suspension dryer, and extrusion through a Glomera high-pressure briquetting press. A commercial plant for Salford, England, was described but apparently never built (5).

Stirrup's d-RDF was in the form of large cyclindrical pieces. No dimensions are given in the early papers, but a single briquet is described as weighing some 2½ pounds.

The next pioneering effort to prepare a specification fuel from MSW in a form that could be burned on a grate was by Hollander and Cunningham (2). They describe a 30-ton-per-hour plant consisting of shredder, classifier, screens, and cubetter to produce cubettes approximately 1½ by 1½ by 2 inches, formed in a modified John Deere alfalfa cuber. Approximately 40 tons of these cubettes were burned with coal (2).

This early work did not lead directly to full-scale plants; perhaps it was just "before its time." Now, however, interest in d-RDF is high, and several organizations are investigating and preparing d-RDF on pilot scales. One plant is doing so on a commercial scale of 60 metric tons per day (4). In 1976-77, the National Center for Resource Recovery equipped its pilot plant to produce d-RDF for investigative purposes; the Center's equipment test and evaluation facility has been described (1).

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[2]Senior research engineer.
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A 300-ton operating period provided fuel for test burns at the powerhouse of the Men's Correctional Institution, Hagerstown, Md., through the cooperation of the Department of General Services, State of Maryland. The test burns were conducted by Systems Technology Corp. under contract to the U.S. Environmental Protection Agency, Office of Research and Development, Municipal Environmental Research Laboratory. The results of these experiments will soon be reported (3). Additional fuel is being prepared and stored for test burns to be conducted in 1978.

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ALUMINUM SCRAP RECOVERED FROM FULL-SCALE MUNICIPAL REFUSE PROCESSING SYSTEMS

by

G. F. Bourcier[1] and K. H. Dale[2]

The growth pattern of the aluminum reclamation (formerly secondary) industry has followed the growth in production and use of primary aluminum. The reclamation industry functions as a supplementary, but very important, source of metal for our economy. Aluminum scrap has comprised 15 to 25 pct of domestic aluminum ingot supply over the last 35 years and has remained at about 22 pct for the last 10 years (1). Today, from our perspective in the aluminum industry, we look at recycling as conceptually capable of providing scrap aluminum through two complementary approaches.

To identify the sources of aluminum scrap and the quantity of scrap available from these sources, a study was made by Battelle Columbus Laboratories that would identify the categories of scrap metal on the basis of its original market (3). The study, published in 1972, was limited to old scrap (that is, metal objects that had been discarded after use). In contrast, new scrap is that scrap recovered directly from manufacturers and fabricators. In 1969, the total quantity of aluminum scrap processed was 1.15 million tons; 200,000 tons of this was old scrap but this was only 13 pct of the available old scrap. By 1975, 334,000 tons of old scrap was recycled; this was an estimated 17 pct of that available. Old scrap usage increased to 416,000 tons in 1976, the last year for which statistics are available.

The advent of resource recovery from municipal refuse has added breadth to the supply of old scrap potentially available to industry. The growing use of aluminum in automobiles indicates that the transportation market, at some point in the future, will provide even more substantial amounts of aluminum scrap and, concurrently, increase the potential market for aluminum scrap (3).

Recovery of aluminum from municipal refuse is not as simple as ferrous recovery. In today's systems, aluminum is generally recovered from shredded or similarly processed refuse after a series of concentrating steps that first remove organics, magnetics, and the fine glass and dirt, leaving a concentrate enriched in aluminum that can be further processed using any of several methods (2).

The first and most widely discussed recovery method is the eddy current separator, of which there are several types now in use. The basis of the eddy current separator is to pass the material to be processed through an electromagnetic field, which for the most part is of a magnitude and frequency that

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[2]Senior development project director.
Both authors are with Reynolds Metals Co., Richmond, Va.

are proprietary to the individual equipment manufacturer and peculiar to his specifications. The electromagnetic field induces eddy currents in any electrical conductor present, which is then repelled by that field.

Another method of aluminum recovery from refuse is the use of dense-media separation, which basically is the flotation of aluminum in an aqueous slurry of magnetite and ferrosilicon, or other dense minerals such as bariet or galena. Nonferrous metals from auto shredders are currently being processed by heavy-media separation facilities in about a dozen separate locations. An analog of these dense-media systems, for processing nonferrous metal concentrates from municipal refuse, is being seriously considered by Reynolds.

The characteristics of aluminum scrap recovered from refuse using eddy current separators include contamination with other nonferrous metals or organics such as rags, paper, and film plastic. This may be compensated for by cleaning up the eddy current separator product with an air knife, screens, heavy-media separation, sweat furnace processing, or handpicking.

The eddy current separators currently in use, although similar in principle, can produce differing grades of aluminum scrap. However, an eddy current separator subsystem can be set up to recover whole or partially crushed aluminum cans and large aluminum scrap objects, such as frozen food dishes, while missing most other aluminum scrap, such as crumpled foil.

Aluminum scrap recovered from processed municipal refuse using dense-media systems will generally be under 2 inches in size and include most of the aluminum in refuse, including scrap cans, castings, foil, etc. Analysis of this scrap may also show small amounts of zinc, insulated copper wire, or glass (which often has the same specific gravity as aluminum). Losses of aluminum to the sink fraction in dense-media processing or to the float fraction in the water elutriation step (generally performed prior to the dense-media operation) could be troublesome if the system is not run properly. In contrast, aluminum recovered from nonmagnetic auto shredder residues will often have a much larger average particle size (nominally in the 2- to 6-inch range) owing to the nature of auto shredders and the physical size of aluminum components in autos vis-a-vis the size of aluminum found in refuse.

Analytical data indicates that current state-of-the-art aluminum recovery equipment is capable of recovering a good grade of aluminum scrap. Additional unit operations may be necessary to upgrade the aluminum scrap recovered, depending on the end use required. There is a ready market for the aluminum scrap recovered if it is consistent in assay recovery and chemistry.

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TEST RESULTS AND APPLICATION IN COMMERCIAL MUNICIPAL SOLID WASTE PLANTS

by

C. Cederholm[1]

The costs of handling domestic refuse are becoming increasingly heavy, while the shortage of raw materials is becoming steadily more acute. Bearing in mind that half of domestic refuse consists of paper and that the raw material for paper is in short supply in Sweden, this is something of a paradox. Thus, there is every reason to apply modern technology to a more efficient use of our raw material resources.

Several factors have thrown recovery techniques into the limelight. According to a large number of forecasts, the shortage of raw materials in Sweden is likely to become increasingly acute in several fields. In particular, a shortage of 1 million tons of paper fiber is predicted by 1980. A large proportion of consumed raw material is available in domestic refuse. Furthermore, the disposal of domestic refuse is expensive and costs increase as environmental demands become more stringent. Costs also increase because existing methods are labor intensive and involve expensive transport operations.

To meet future requirements and obtain an economic utilization of resources, Sweden passed a law in mid-1975 giving the Government full authority to demand that each community with the financial means start a first-stage sorting operation for newspapers and magazines. A preparatory period of 5 years has been allowed prior to application of the new law, so that communities can make necessary preparations and investigations as regards suitable methods.

To a certain extent, and with varying degrees of success, the idea of recovery has long been applied at the source in collection campaigns. Experiments in carrying this out on a more regular and controlled basis have been made in the past and are continuing. However, collection at the source has a number of shortcomings. These include the following:

1. The costs of collection and special treatment are fairly high.

2. The sorting discipline varies.

3. Uncontrolled proportions of materials are collected.

4. Unsatisfactory flexibility in adapting the collection to new and varying requirements.

It is, therefore, very important to study alternative solutions employing central treatment plants, in which unsorted refuse can, basically, be fed into one end and usable raw materials discharged from the other (fig. 1).

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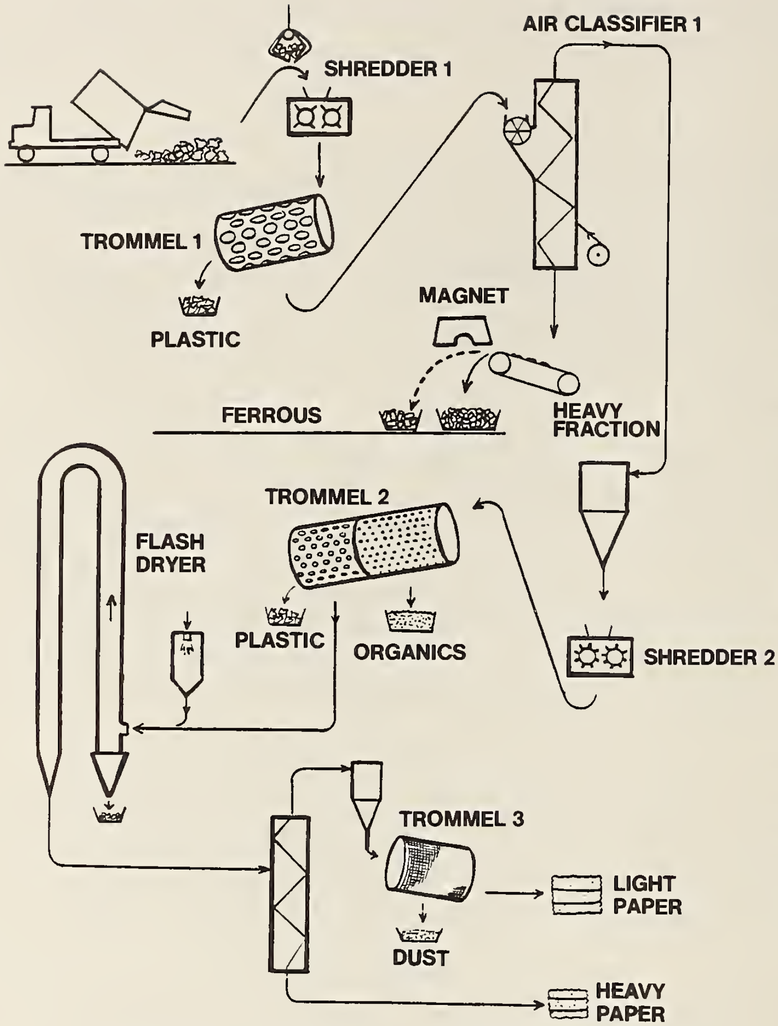

FIGURE 1. - Flowsheet of RRR pilot plant in Stockholm, Sweden.

During recent years, a large number of tests have been carried out and pilot plants operated all over the world. The term "recovery" has become a catchword which is used and abused to justify a wide variety of activities. Recovery is a common term for a number of technical solutions adopted to utilize, partially or entirely, the latent economic value of refuse. Recovery can be divided into three categories:

Direct recovery of substances.--Material recovered becomes new products similar in nature to the original products.

Indirect recovery of substances.--Material recovered may be used for new applications that differ entirely from the original product.

Recovery of the energy content in refuse.--Material recovered is used in combustion, pyrolysis or biochemical decomposition processes, which liberate heat or produce fuel.

The value of the material recovered is obviously a very important factor, since it affects the revenue from the recovery process.

Analysis of the annual operating and capital costs of a recovery plant is equally important, in order to establish profitability at varying levels of revenue from recycled materials. It should be clearly borne in mind that the present, relatively expensive methods of disposal need not necessarily be turned into profitmaking ventures in the future. As a first stage, it is sufficient to reduce the overall handling costs.

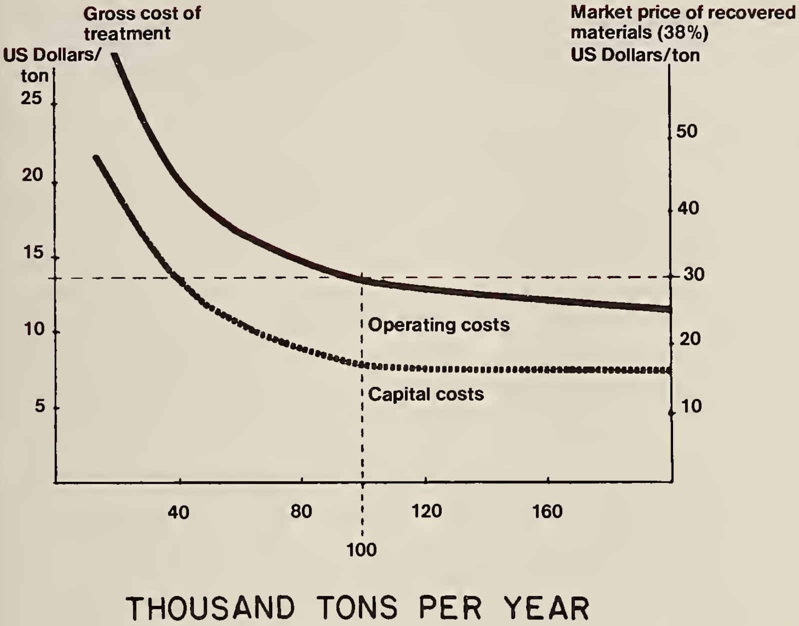

FIGURE 2. - Gross cost of treatment in relation to plant capacity.

Figure 2 gives an example of the specific costs of processing and the revenue per ton of processed material, after allowances for operating costs and depreciation (10 years for machines, 20 years for buildings, and a 10-pct rate of interest). It relates to a plant with an assumed capacity of 100,000 tons per year. The operating costs, including energy (and heat for drying), maintenance, service and personnel, amount to approximately \$5 per ton, whereas the annual capital costs amount to \$8 per ton. This means that the average revenue from the material recovered (paper and ferrous metals) at an efficiency of 38 pct and selling at \$30 per ton would make the system economically self-supporting.

Research and development work has led to functional and practical systems for the recovery of materials, thus allowing communities to conserve their resources and at the same time significantly reduce processing costs.

The profitability aspect changes radically with respect to raw materials. What was earlier regarded as useless suddenly gains in value. Municipal solid waste can thus become an important raw material in the production cycle. The recovery of materials will also have an important role to play in the national economy, owing to the energy gains that can be made in refining recycled material as compared with fresh raw material. Moreover, significant environmental gains can be achieved by reducing pollution of earth, air, and water.

PROGRESS IN PRODUCING DETINNED STEEL FROM URBAN REFUSE MAGNETIC FRACTIONS

by

H. V. Makar[1] and E. L. Gresh[2]

Two processes have been developed by the Bureau of Mines, U.S. Department of the Interior, for recovering materials of value contained in urban refuse as part of the Bureau's mission to conserve the Nation's mineral resources through secondary recovery. One process applies to municipal incinerator residues and the other to raw, unburned refuse. Both are operated regularly on a pilot scale, and details have been published previously (4, 7, 10-11). Current research is concentrated on raw refuse processing, with a lesser, but significant effort on incinerator residues. Intense interest has developed in this country and abroad toward implementing "front-end" separation technology. Several commercial-scale units are already in operation, and others are in various stages of planning or construction (12). Thus, a resource recovery industry for improved management of urban refuse is developing rapidly.

In the meantime, there is much that can be done on a pilot scale to aid government and private organizations in planning new plants and in determining the recyclability and value of materials reclaimed from refuse. To meet such a need, a raw refuse pilot plant in Edmonston, Md., is operated on a regular basis to (1) generate products for analysis and suitability for recycling, (2) provide technical assistance to government and other organizations to enhance technology transfer, and (3) continue evaluation of the existing process flowsheet and determine what, if any, modifications should be made to accommodate refuse composition variations or to improve product recovery and quality.

Evaluations of products generated in the pilot plant are conducted in-house and by potential consumers to establish recyclability and market acceptance. Standards for ferrous scrap from urban refuse are currently under development in Committee E38 of the American Society for Testing and Materials (ASTM). These include specifications for chemical composition and certain physical requirements for scrap destined for five different industries. Proposed standards under consideration are summarized in table 1. In addition to the chemical and physical requirements shown, the proposed specifications include limitations regarding form (baled or loose) and processing technique (incineration, shredding).

Properly prepared scrap could meet most of the proposed specifications without detinning, but use would be restricted to relatively small quantities to minimize buildup of residual elements. After detinning, however, the scrap can be used with few restrictions and command the higher prices typical of the

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traditional top grades of scrap. In addition, the tin resource contained in the scrap is recovered as a separate product.

TABLE 1. - Proposed specifications for ferrous scrap from refuse, pct

Component[1]	Industry				
	Copper precipitation	Iron and steel		Detinning	Ferro-alloy
		Foundries	Production		
Carbon	NAp	NAp	NAp	NAp	0.6
Manganese	NAp	NAp	NAp	NAp	.35
Phosphorus	NAp	0.03	0.03	NAp	.03
Sulfur	NAp	.04	.04	NAp	NAp
Silicon	NAp	NAp	.10	NAp	NAp
Nickel	NAp	.12	.08	NAp	NAp
Chromium	NAp	.15	.10	NAp	.15
Molybdenum	NAp	.04	.025	NAp	NAp
Copper	NAp	.20	.10	NAp	.20
Tin	NAp	[2] .30	.30	0.15 min.	.30
Lead	NAp	.03	.15	NAp	NAp
Zinc	NAp	.06	.06	NAp	NAp
Aluminum	NAp	.15	.15	4.0	.15
Titanium	NAp	NAp	NAp	NAp	.025
Metallic yield min...pct..	([3])	90.0	90.0	([4])	90.0
Combustibles, max....pct..	.2	4.0	4.0	NAp	.5
Bulk density......lb/ft^3..	30.0	50.0 min.	75.0 min.	25.0 min.	50.0 min.

NAp Not applicable.
[1]Maximum limits, unless otherwise designated.
[2]Tin limit for steel casting is 0.10 maximum.
[3]96 pct iron, minimum.
[4]A minimum of 95 pct of scrap shall be magnetic.

Detailed data on chemical composition are extremely limited for the various commercial grades of steel scrap currently marketed. Table 2 summarizes various scattered data that have been published (3, 5, 8-9). Other published data for tin content show 0.025 pct average for all purchased scrap and up to 0.075 pct in iron ore (2). The chromium coating on tin-free steel cans represents less than 0.01 pct (1, 6). Even at the higher percentage of 17 pct tin-free cans shown in table 3, chromium in the scrap attributable to this source would be less than 0.002 pct.

The Bureau of Mines, in cooperation with the industry, has evaluated the suitability of ferrous scrap from raw refuse as a raw material for existing detinning operations. Tests ranged from in-house, laboratory-scale detinning to full-scale commercial detinning arranged for and conducted by a commercial detinner. The significant results are summarized as follows:

1. It is technically feasible to reduce surface tin on refuse-derived scrap to levels as low as 0.01 pct, on a thoroughly rinsed detinned product.

2. On a practical commercial scale, final tin content will include a combination of tin unleached from the surfaces and solder seams, the tin-bearing solution that cannot be completely rinsed off, and tin from solution carried out through absportion in paper, fabric, and wood.

3. Unleached tin can be minimized by reshredding the scrap without balling. This achieves greater dislodging of lacquer coatings and rupturing of seams. Shredding also allows for freer flow of the detinning solution and more thorough draining after detinning.

4. Solution carryover is minimized by combining air classification and magnetic separation with shredding. This removes combustibles and dirt which absorb caustic solution and reduce metallic yield.

5. Preliminary results from 10-ton lots indicate that the primary objective in the commercial-scale test of achieving a tin residual of 0.06 pct maximum was attained.

6. Additional phases of the 150-ton test will establish optimum preparation steps for the ferrous scrap from municipal refuse and demonstrate steel quality in production melts.

TABLE 2. - Examples of commercial scrap quality

Type of scrap	Chemical composition, pct								Yield, pct	Bulk density, lb/ft[3]
	Cu	Sn	Cr	Ni	Mo	Pb	P	S		
No. 1 heavy melting......	0.16	0.001	0.05	0.08	0.028	NA	0.015	0.025	90-94	NAp
No. 1 factory bundle.....	.06	.005	.04	.04	.03	NA	NA	.025	88-91	75 min.
Shredded autos...........	.22	.021	.16	.10	.02	0.01	.023	.039	92-94	50-110
Detinned bundle[1] (revert, prompt industrial)......	([1])	[2].04	([1])	([1])	([1])	([1])	([1])	([1])	90	120-160
No. 2 bundle (non-auto)..	.38	.038	.10	.08	.02	NA	.012	.048	84-86	75 min.
No. 2 bundle (auto)......	.48	.08	.12	.10	.02	NA	NA	.08	76-87	100
Base steel[3].............	.03	.009	.02	.02	.001	NA	.011	.024	NAp	NAp

NA Not available.
NAp Not applicable.
[1]Detailed analysis not available. Other elements assumed to be comparable to that of the base steel.
[2]Typical range = 0.036 to 0.048 pct.
[3]Analysis of base steel used for canmaking (Bethlehem Steel Corp., private communication).

TABLE 3. - Composition of ferrous samples from 10-ton lots, pct

Component	Lot 1[1]	Lot[2]
Tin-plated cans..	49.6	46.1
Bimetal tin-plated cans......................................	2.4	2.9
Bimetal tin-free cans..	15.8	17.0
Bottle and jar caps..	2.1	2.7
Paperboard containers with metal ends........................	NA	NA
Miscellaneous magnetics......................................	29.2	30.3
Loose combustibles...	.8	1.1

NA Not available.
[1]10-ton lot subsequently air-classified and magnetically separated.
[2]10-ton lot subsequently reshredded, air-classified, and magnetically separated.

It can be concluded from evaluations to date that ferrous scrap from municipal solid waste can be commercially detinned to an acceptable level with proper scrap preparation. The preparation must remove as much contamination as possible (organics, combustibles, nonferrous metals). The processing must also open whole cans as much as possible to allow the solution to circulate freely and drain upon removal from the tank. Finally, an effective method of processing to accomplish the desired preparation follows: Reshredding the scrap, air classifying to remove light organics and combustibles, then magnetically separating the scrap to eliminate any unwanted heavy nonmagnetic material such as wood and nonferrous metal. This method is similar to that recommended by the Bureau of Mines on its scaled-up flowsheet for raw refuse processing (7).

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MONROE COUNTY RESOURCE RECOVERY FACILITY

by

D. B. Spencer[1]

The Monroe County (N.Y.) Resource Recovery Facility (RRF) is designed to process municipal, commercial, and light industrial waste at a rate of approximately 127 metric tons per hour (140 tph), figure 1. Two fully identical primary process lines will extract ferrous metals and a light paper fraction which will be burned as a supplementary fuel in utility boilers for power generation or, alternatively, reclaimed as paper in the future.

The process that will be utilized was developed by Raytheon and is based heavily on experimental work performed by Raytheon and the U.S. Bureau of Mines (USBM) at the USBM Raw Refuse Processing Pilot Plant in Edmonston, Md., under a cooperative agreement for testing and scale-up of resource recovery technology. Similar to operations at the USBM plant, shredding and air classification will be performed in multiple states in the Monroe project. In addition, however, it is planned to utilize a rotary-drum air classifier and nonferrous metal separator developed independently by Raytheon Co. and Iowa Manufacturing Co., a Raytheon subsidiary engaged in the manufacture of heavy process machinery.

Establishing product quality and confidence levels and market development have been key parts of the work performed on this project. This has included testing sample products over a wide range of pilot plant tests, optimizing processing techniques to improve product quality, and testing sample products by potential users in their own operations.

A 20-year agreement has been reached between Monroe County and Rochester Gas & Electric Co. (RG&E) for purchase of the RDF product. This agreement requires RG&E to utilize as much fuel as is possible up to the maximum available from the facility and to pay 100 pct of the net value of coal saved after adjustments for all incremental costs incurred by RG&E for cofiring of RDF with pulverized coal.

Raytheon has negotiated firm agreements for sale of the glass to Owens-Illinois, the aluminum to Reynolds Metals, and the ferrous metals to Vulcan Materials. All these agreements are tied to market indices, have floor prices, and are for 5 years from the date of full commercial operation of the facility.

[1]Project manager, Raytheon Service Co., Burlington, Mass.

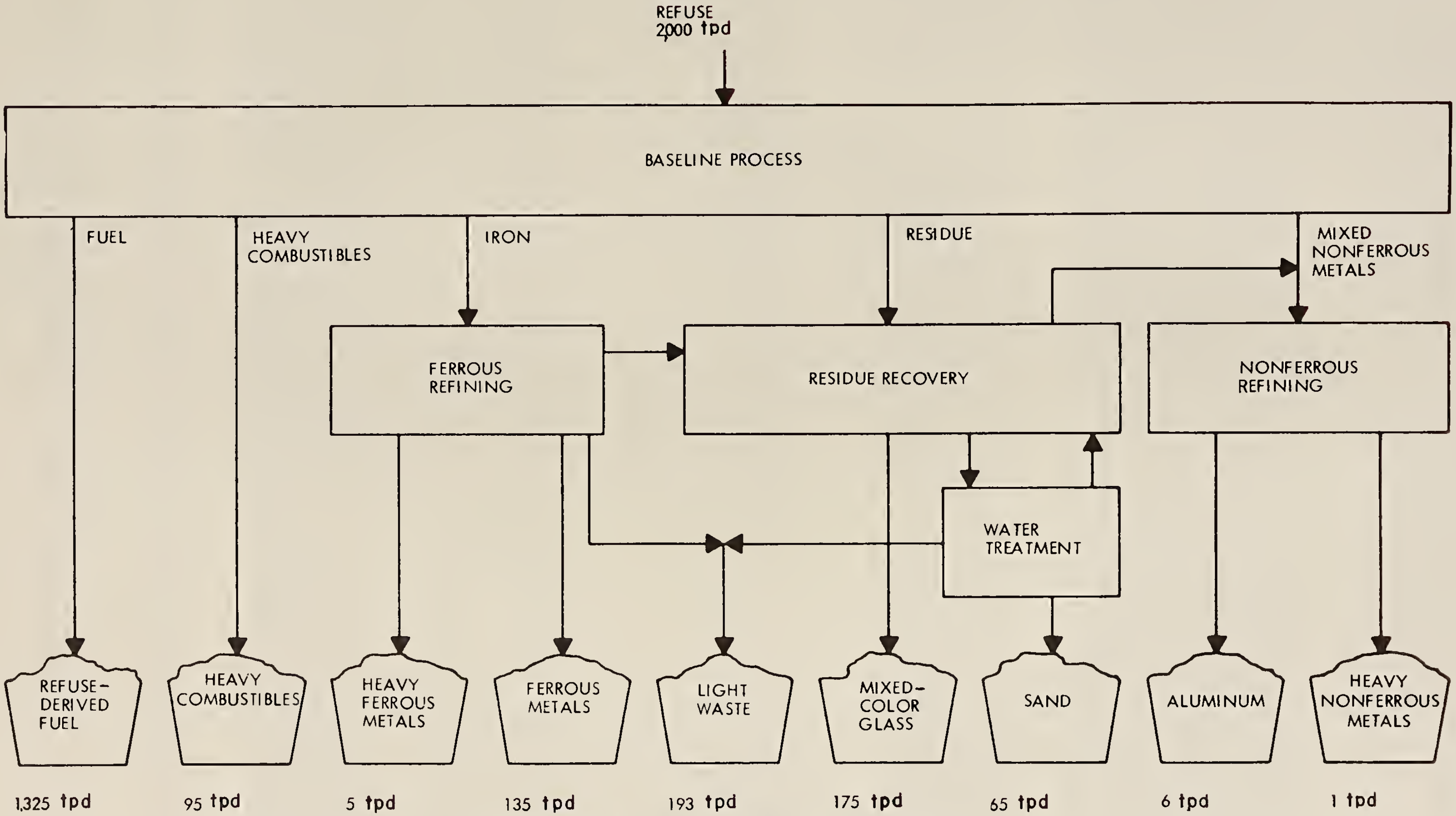

FIGURE 1. - Process system configuration.

PROMISING APPLICATIONS FOR MUNICIPAL INCINERATOR RESIDUES

by

R. J. Collins[1]

Incineration is a principal means of solid waste disposal in many metropolitan areas of the United States. The primary advantage of incineration is that it reduces the volume of incoming solid waste by 80 to 90 pct, thus extending the life of existing landfills. Nevertheless, a residue is produced after burning, which represents from 20 to 40 wt-pct of the original refuse. The residues are a soaking wet mixture of glass, metals, ash, minerals, and combustible matter and must be disposed of in an environmentally acceptable manner.

There are approximately 140 municipal incinerator plants currently in operation throughout the United States. These plants generate a combined total of 5 million tons of incinerator residue annually (3). Although incinerators are located in 24 States and the District of Columbia, the largest concentration of plants is found in the Northeast, particularly in Connecticut and New York.

Incinerator residue is a heterogeneous material derived from the combustion of municipal refuse. Essentially, municipal refuse is composed of a combustible fraction (paper, food wastes, wood, textiles, yard wastes, etc.) and a noncombustible fraction (metals, glass, ceramics, bricks, rocks, etc). Although the composition and moisture content of refuse does vary during different times of the year and in different parts of the country, the combustible fraction normally represents 60 to 80 wt-pct of the incoming refuse (2).

The proper combustion of solid waste in municipal incinerator plants is influenced by three basic factors: Time, temperature, and turbulence. The refuse must be exposed to temperatures of 1,600° to 1,800° F long enough for satisfactory combustion. In general, the more the refuse is agitated during burning, the higher the degree of burnout.

Degree of burnout can be defined as the ratio of the incinerated refuse to the combustible fraction of the refuse. It is dependent primarily on the type of incinerator furnace and the grate system used for feeding refuse through the incinerator, although differences in plant operation also affect burnout. For practical purposes, municipal incinerator residues can be broadly classified into three categories, based on degree of burnout, as follows:

1. Well-burned-out.--These residues comprise approximately 10 vol-pct and 20 to 30 wt-pct of refuse input (1).

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2. Intermediately burned-out.--These residues usually represent approximately 20 vol-pct and 25 to 35 wt-pct of refuse input (1).

3. Poorly burned-out.--These residues comprise about 30 to 40 wt-pct of the refuse input (1).

Municipal incinerator residues, although heterogeneous in nature, are predictable in their composition and gradation. Past experience and the results of extensive study have shown that these residues are suitable for use in embankments, landfills, subbases, stabilized base courses, and bituminous paving mixtures with a minimal amount of processing. Well-burned or intermediately burned residues are acceptable for such uses. Some aging is recommended for all residues prior to use. Extended aging for 6 to 12 months is needed to improve the characteristics of poorly burned residues.

At present, the use of residue in bituminous paving appears to be the most promising application of this material. Residue use is more highly recommended in base course applications. The residue should be blended on an equal-weight basis with natural aggregate. The addition of hydrated lime is also required to improve asphalt adhesion. Residue paving mixtures can be mixed, spread, and compacted using methods and equipment normally employed in conventional asphalt paving.

Some consideration should also be given to the use of incinerator residue as a synthetic aggregate through heat fusion and in the production of structural brick and mineral wool insulation. The energy requirements and economics associated with each of these applications must be carefully investigated.

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FIBER RECOVERY FROM MUNICIPAL SOLID WASTE

by

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and G. J. Trezek[1]

Depletion of our national forest reserves coupled with an increasing public reluctance to allow the opening of new timber areas to harvesting has resulted in a decreased supply of the basic raw material for pulp and paper production, namely wood. One consequence of this dwindling supply is rising prices for lumber as well as for paper products. In addition to the poor economic consequences, the harvesting of vast regions of timber may pose serious climatological consequences. Evidence is available that supports the contention that destruction of forests has a deleterious effect on the carbon dioxide balance of the atmosphere, with the net effect being the possibility of altering the world climate (3).

As an alternative to the use of forest lands for securing the raw material for pulp and paper production, the possibility exists for exploiting a heretofore-untapped source of cellulosic fiber; that is, the paper fiber present in solid waste presently being landfilled. In this paper the means of recovering paper fiber from this refuse will be explained. At the same time the properties of handsheets formed from fiber recovered from solid waste will be presented and compared with those of other types of wastepaper. Successful and efficient recovery of fiber from the municipal solid waste stream requires an encompassing management plan ranging from solid waste processing to pulp mill technology. We have examined fiber recovery from the standpoints of refuse collection, mechanical preprocessing, hydropulping, cleaning, water treatment, and determination of recovered pulp properties.

As previously reported by Trezek and Golueke (2), experiments conducted at the Richmond Field Station of the University of California (Berkeley) have shown that fiber recovery from municipal solid waste is technologically feasible provided that a certain processing sequence is followed. The overall system consists of a dry process followed by a wet process, which includes water.

The main components of the dry processing are (1) a hammermill grinder (rated at 10 tons per hour), (2) a vertical air classifier, (3) a cyclone and air-lock feeder, and (4) a rotary cylindrical screen (trommel). The system is capable of processing up to 4 tons of refuse per hour and typically produces a wastepaper fraction in the range of 40 to 60 wt-pct of the input total. The wastepaper serves as a feedstock for the wet processing system. The percentage of the raw waste that is recovered as wastepaper fraction is dependent upon the type of waste being processed; that is, residential or commercial. The processing sequence has succeeded in reducing the water quality problems associated with the pulping of refuse-derived pulp so that conventional

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waste-water treatment can be employed. Fiber recovered from residential solid waste exhibits strength characteristics similar to those of 100-pct-deinked newspapers and virgin groundwood. On the other hand, fiber recovered from commercial solid waste possesses slightly greater strength properties, similar to those of a typical newsprint furnish of groundwood and chemical pulp.

The cellulosic content of urban solid waste is considerable. Presently, some 2 million tons of paper per year are landfilled in the San Francisco area alone (1). Given the technical means as described here for fiber recovery, the solid waste stream can be viewed as a resource to be exploited. It is hoped that this research will stimulate the recovery and utilization of fiber from solid waste. Not only would fiber recovery reduce energy and raw material expenditures within the pulp and paper industry, but the present disposal problem of postconsumer fiber would be greatly reduced or eliminated.

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RECOVERY OF GLASS FROM URBAN REFUSE BY FROTH FLOTATION

by

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As part of its research program, the Bureau of Mines, U.S. Department of the Interior, investigates new or improved metallurgical technologies that are needed to help maintain adequate material and metal supplies while conserving natural resources through the recovery of values from secondary resources such as urban refuse. A process was devised and a pilot plant was constructed to reclaim valuable materials from the residues of municipal incinerators (2). Products from the primary section of the pilot plant include clean ferrous scrap, mixed nonferrous metals, and glass aggregates. A major portion of the current flowsheet is shown in figure 1.

Following development of the incinerator residue system, a companion process was developed and a pilot plant constructed to recover materials from unburned urban refuse (4). Products reclaimed in this pilot plant include ferrous scrap, aluminum, mixed heavy nonferrous metals, glass aggregates, and combustibles for use as fuel (3). A major portion of the raw refuse flowsheet is shown in figure 2.

Glass aggregates recovered in both systems contain approximately 10 pct nonglass materials (principally ceramics, brick, and stones), making the products unsuitable for use as cullet in the manufacture of glass containers. To be acceptable for use as cullet, glass recovered from urban waste must meet a rigid set of specifications that has been imposed by the glass container industry (1). The most critical requirement involves the permissible number of refractory particles that can be tolerated in a specified quantity of cullet. The minus 20- plus 40-mesh fraction of a 1-pound sample of cullet (minus 20- plus 150-mesh), in which there are an estimated 600,000 particles, cannot contain more than 2 refractory particles, and the minus 40- plus 60-mesh fraction cannot contain more than 20 particles.

The specifications include the statement, "for the purpose of evaluating cullet coming from a municipal resource recovery system, these particles will be considered refractory until the glass container manufacturer can certify otherwise." The particles referred to are foreign particles in a 1-pound sample of cullet that are separated from the glass by heavy liquid at 2.65 specific gravity. Corundum, mullite, zircon, chromite, spinel, sillimanite, andalusite, kyanite, and cassiterite are listed as being refractory in sizes larger than 60 mesh. Ceramic ware, vitreous clay, chinaware, bricks, tile, gravel, and concrete fragments are objectionable since they can result in partially fused inclusions in the finished glass. Metallic aluminum, radio tube parts, spark plug porcelain, chrome ore, or chrome refractory in any amounts are the most objectionable cullet contaminants.

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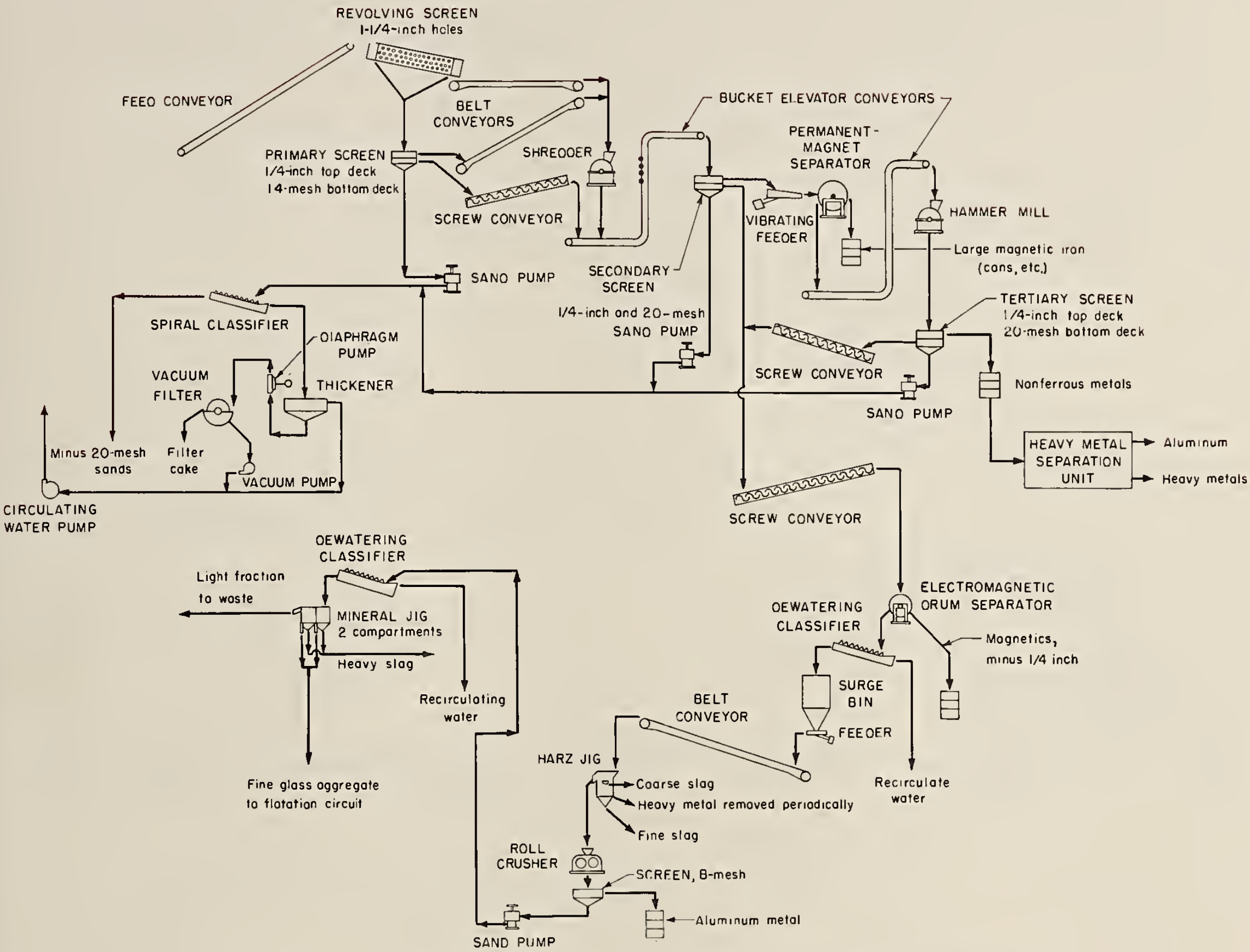

FIGURE 1. - Municipal incinerator residue recovery flowsheet.

Even though these specifications were not available during the early years of research on incinerator residues, it was evident at that time that the minus 20-mesh aggregate remaining from nonferrous metal recovery operations would not be suitable for use as cullet. Pioneering research was begun to determine whether a clean glass product could be prepared using conventional minerals beneficiation technology, specifically froth flotation. The principal objective at that time was to obtain a marketable product by floating all of the nonglass material away from the glass. Test results gave no real evidence of success for this approach, and the test program was recessed.

In 1970 testing was resumed with the new objective of floating glass away from all nonglass materials. From the start, it was evident that this approach had potential for success, and by mid-1972 results were so encouraging that a decision was made to add a glass flotation section to the pilot plant operations.

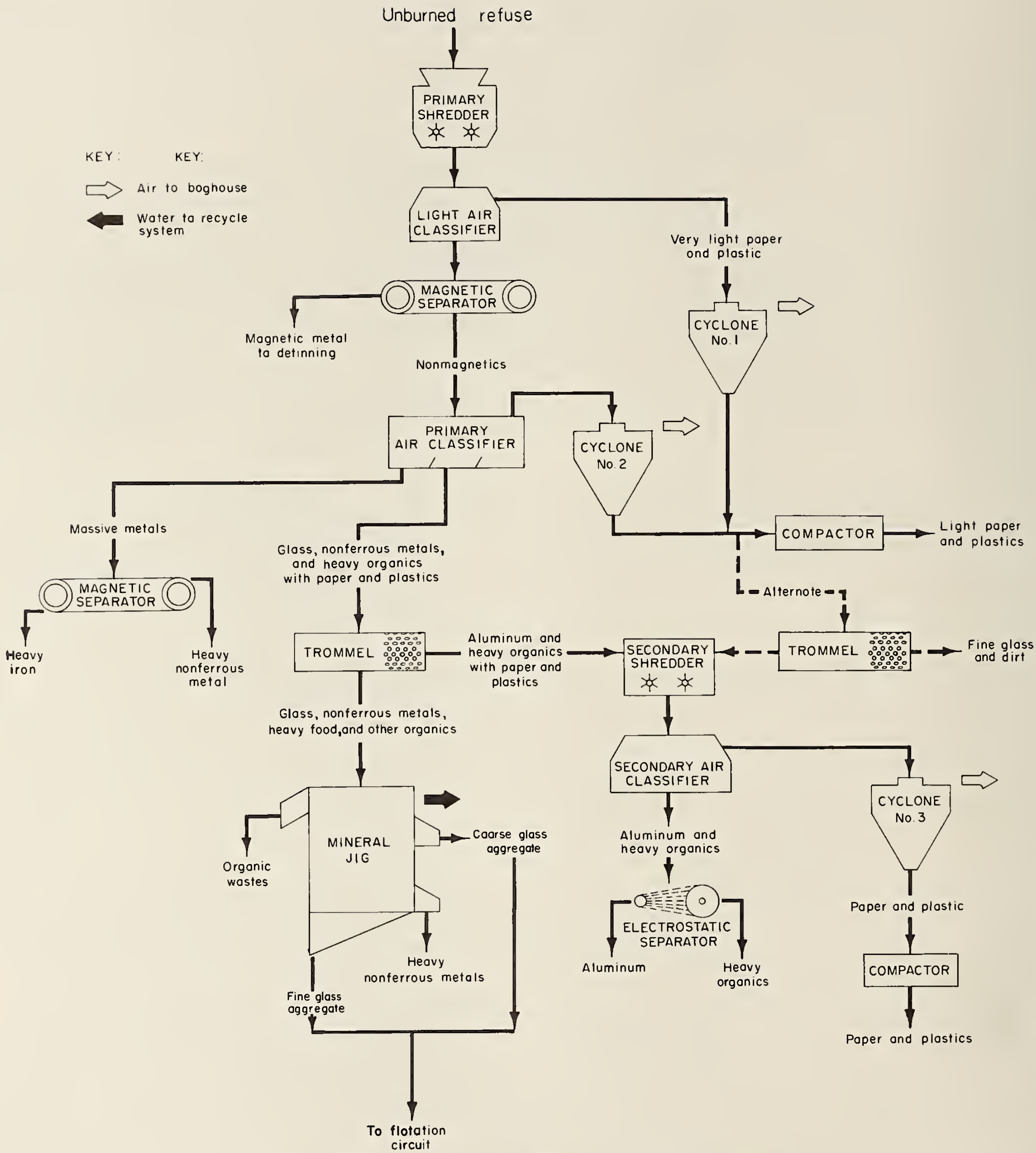

FIGURE 2. - Raw refuse separation flowsheet.

Experience gained from pilot plant operations (fig. 3) makes it unsafe to say that the day-in and day-out production of flotation concentrates will meet the stringent cullet specifications in continuous operations; that is, this is due to the existing lack of precise quality-control methods, the human fallibility of operators, and the inaccuracies that are possible with current methods of product evaluation.

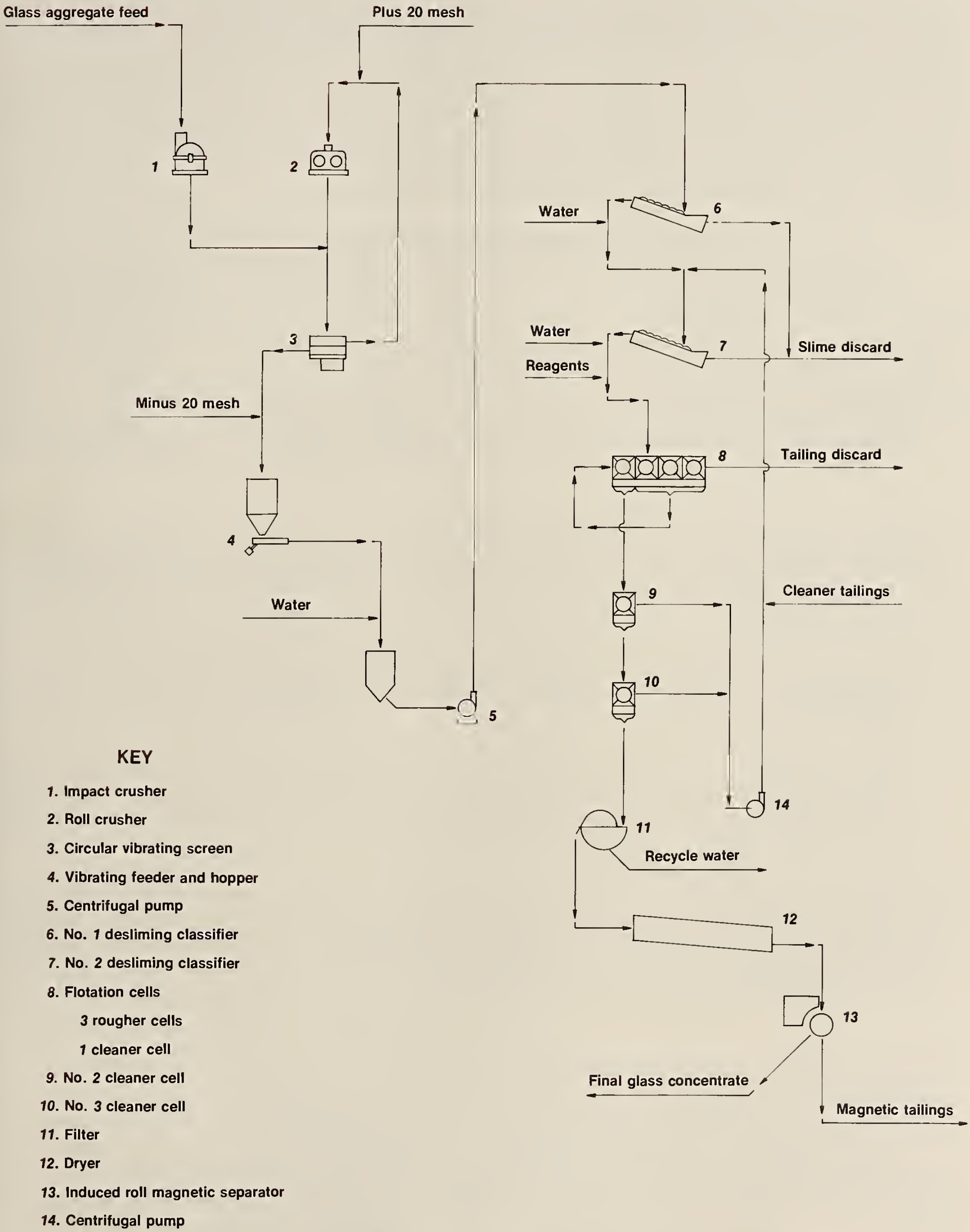

FIGURE 3. - Flowsheet of continuous glass flotation section.

It has been demonstrated by batch and continuous testing, (table 1) that cullet-quality glass products can be recovered from solid waste streams by froth flotation. The technology and equipment involved have been highly developed in the minerals industry. The glass product of this technology is untried commercially, but the fact that three resource recovery plants are now under construction that will use froth flotation in glass recovery systems demonstrate confidence in the emerging resource recovery industry that this product can be used to make new glass containers.

TABLE 1. - Summary of pilot plant operations

Product	Wt-pct	Glass pct[1]	Glass distribution, pct
Slime discard......................	11.3	90.0	13.7
Flotation tailings.................	16.2	40.0	7.3
Flotation concentrates.............	70.3	99.9	79.0
Composite..........................	100.0	88.9	100.0

[1]Glass content of all products was either estimated or calculated.

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TEST PROCEDURES FOR DETERMINING THE GROSS CALORIFIC VALUE OF REFUSE AND REFUSE-DERIVED FUELS BY OXYGEN BOMB CALORIMETRY

by

D. R. Kirklin,[1] D. J. Mitchell,[1] J. Cohen,[1] E. S. Domalski,[1] and S. Abramowitz[1]

The recovery and utilization of energy from solid waste have been the subject of much interest since concern is being expressed about our fuel shortages. Fossil fuels are presently being used in powerplant boilers to generate steam for energy purposes. Solid waste is a potential source of fuel that can be utilized in powerplant boilers to generate steam for energy purposes. Therefore, much research is centered around the conversion of solid waste to energy. Before solid waste can be effectively utilized in powerplant boilers, much testing is necessary. The areas of solid waste analysis, ash analysis, emission testing, corrosion testing, and boiler performance are of primary concern.

The American Society of Mechanical Engineers (ASME) Committee for Performance Test Code 33--Large incinerators (PTC-33) has indicated that a need exists to find a more accurate test procedure for the determination of calorific values of refuse and refuse-derived fuels (RDF) that will more accurately represent a corresponding large array of collected raw refuse. If an improved calorific value test procedure is available to the ASME PTC-33 committee, it can offer a mechanism by which public works administrators and private owners can evaluate with greater accuracy and higher confidence than is presently possible whether or not their large incinerators and refuse-fired boilers are in compliance with their contract performance specifications. The E-38 Committee on Resource Recovery of the American Society of Testing and Materials (ASTM) is interested in establishing refuse-derived fuels (RDF) as an article of commerce. A laboratory procedure giving reproducible results will better equip commercial laboratories to certify accurately the energy content of RDF of various compositions. As an article of commerce, RDF can be bought and sold as a regulated low-sulfur fuel to supplement other fossil fuels. The U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) are collaborating in resource recovery programs to facilitate the development of various waste-to-energy technologies. The need for information on the calorific value of waste streams has been acknowledged by incinerator operators and designers.

The quantity of energy liberated per unit mass of refuse burned (gross calorific value of refuse) can be directly obtained from a bomb calorimetric experiment. The techniques of bomb calorimetry are well characterized (4-5). Bomb calorimetry is used extensively in the determination of the calorific value of various fossil fuels (1). Therefore, it would be extremely advantageous to be able to accurately determine the calorific value of refuse and RDF by bomb calorimetric methods.

[1]All of the authors are with the National Bureau of Standards, Washington, D.C.

However, municipal refuse is far from being an easily characterized homogeneous fuel. Its makeup can vary widely, depending upon many geographical, seasonal, and weather-related factors. This variability will affect both a refuse stream's potential as a fuel source and its potential as a source of environmental pollution.

The objectives of the research program are threefold:

1. Development of test procedures to determine the gross calorific value of refuse and RDF by bomb calorimetric methods.

2. Evaluation of sample characteristics by analyzing for moisture, ash, carbon, sulfur, and chlorine.

3. Evaluation of the homogeneity and sample preparation requirements for bomb calorimetric experiments utilizing two bomb calorimeters which have capabilities for handling samples that differ by an order of magnitude in mass (that is, 2.5 g and 25 g).

Refuse has five forms: (1) As-received refuse with the "white goods" removed ("white goods" are items such as refrigerators, stoves, and sinks); (2) shredded refuse of 2.5 to 7.5 cm (1 to 3 inch) particle size; (3) shredded refuse with the "heavy fraction" removed ("heavy fraction" is the noncombustibles such as glass and ceramics); (4) refuse pellets; (5) refuse powder. Forms 3, 4, and 5 are considered RDF. The sample preparation required to prepare a bomb calorimetric sample from any of the five forms is such that the bomb calorimetric sample is definitely an RDF. In fact, the preparation of a homogeneous sample for a calorific determination (regardless of the technique to be utilized) is the processing of an RDF of some degree. Therefore, the initial testing performed in this research project started with forms 4 and 5.

Materials used in the program were a standard reference sample of benzoic acid obtained from the National Bureau of Standards, Ultra High Purity-grade oxygen from Matheson Gas Products, Teledyne National RDF, and Combustion Equipment Associate RDF (ECO-II RDF).

Results on a limited number of samples have demonstrated that RDF samples can be processed for bomb calorimetric experiments to produce results with a precision (standard deviation of a measurement) approximately equal to or better than 1 pct. The calorific values[2] determined at three stages of sample preparation showed no overwhelmingly significant differences. For Teledyne National samples, the calorific values slightly increased with increased sample processing, but opposite trends were observed for ECO-II samples. Moreover, the percent deviation (for moisture- and ash-free RDF) based on all three types of samples was 0.802 pct for Teledyne National RDF and

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[2]Owing to the arbitrary selection of the RDF field samples, the precision obtained by the reported procedures is the most significant result. In no way does NBS imply that the experimental results presented are typical of the average stream of the RDF's tested.

0.424 pct for ECO-II RDF. Percent deviations between two types of either Teledyne or ECO-II RDF's ranged from 0.21 to 0.94 pct.

Our standard deviations of a measurement are much less than one would initially expect for something as nonhomogeneous as refuse. This was achieved by using the amount of combustion residue of each experiment to calculate an MAF calorific value rather than an average ash value. For some RDF samples the ash values are not constant. Noncombustibles must "stick" to RDF particles and are therefore not uniformly distributed throughout the RDF samples. Therefore, a more precise ash-free heating value can be calculated using the amount of ash contained in each combustion sample.

Coals of various ranks have typical moisture- and ash-free (MAF) gross heating values (2-3) ranging from 34.89 to 25.59 MJ kg^{-1} (15,000 to 11,000 Btu lb^{-1}). Our MAF-RDF results ranged from 25.20 to 21.93 MJ kg^{-1} (10,835 to 9,427 Btu lb^{-1}). Our results are based upon two 20-kg (44-pound) field samples of RDF, which automatically makes it impossible to evaluate whether our results[3] are typical of the RDF's produced by either manufacturer. However, RDF's calorific value makes it definitely a viable competitor of some low-rank lignites. Also bituminous coals typically demand a greater degree of fineness than low rank coals to achieve complete carbon burnout (3). The necessary degree of fineness for RDF's may even be less (that is, larger particles) than that for the low-rank coals.

All fuels contain mineral matter that goes through varying stages of decomposition and recomposition in the combustion process. It all ends up either as bottom ash or fly ash. Coal may have ash contents of the order of 10 pct, compared with the 12 pct values we experienced with RDF. However, ash fusibility data re necessary to properly evaluate the ash problem presented by refuse and RDF.

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[3]See footnote 2.

OPERATING ECONOMICS OF THE CITY OF AMES RESOURCE RECOVERY SYSTEM

by

S. H. Russell[1] and M. K. Wees[1]

The Ames, Iowa, resource recovery system, which processed an average of 186 tons per working day in 1977, is shown in schematic form in figure 1. The refuse is processed by two stages of shredding, magnetic removal of ferrous metals, air density separation, and nonferrous metals separation. The metals are sold, and the refuse fuel is stored, then fired as a supplement to coal in the city-owned powerplant. Details of the system's equipment have been presented in other references (1-2). Startup and equipment shakedown began in September 1975.

After startup, the system's design engineering firm (Henningson, Durham & Richardson) began an operations monitoring program. Information was scarce during the first few months of operation, because the city's accounting system for the new municipal entity had not yet been finalized. As more information became available, the calculations and reporting became more complex. A computer-based management information system (MIS) has therefore been developed to aid in operations monitoring. Operating data are entered (or changed) and reports are generated with an interactive computer program which requests the required information with a series of questions in English. This feature allows for use of the MIS by persons not familiar with the programing, or even by persons unfamiliar with computers.

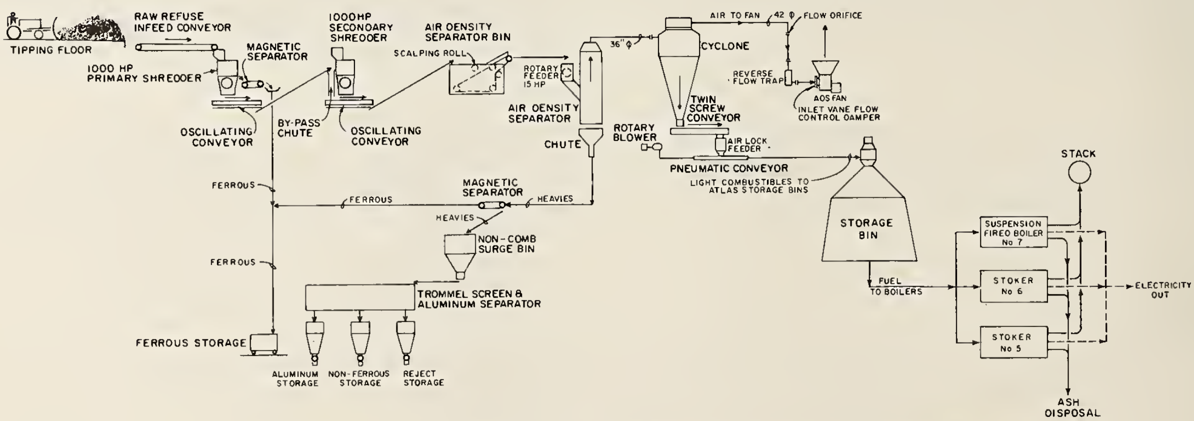

FIGURE 1. - Schematic of Ames resource recovery system.

[1]Environmental engineers, Hennington, Durham and Richardson, Omaha, Nebr.

The following is a discussion of results obtained after running the unit for the year 1977. Data were obtained through the use of the MIS.

Materials Balance

Over 48,000 tons of solid waste was processed by the system in 1977, which is an average of about 4,000 tons per month, or 186 tons per working day. About 3,000 tons of ferrous metals (6.2 pct of total waste stream) were sold at an average of $31.5 per net ton before transportation charges during the year. Almost 84 pct of the total was converted to fuel with an average value of about $1.15 per million Btu. Smaller amounts of other materials were recovered.

Energy Balance

About 2.8 million kwhr was consumed by processing, storing, and conveying the refuse (an average of about 60 hwhr/ton processed), while about 19.3 million kwhr was produced from burning the prepared fuel. This represents an average out-in ratio of 7:1 (a low of 4:1 and a high of 10:1).

Costs

Total facility costs for the year were about $1.1 million (which includes $100,000 in startup cost repayment), or about $22.70 per ton. Total revenues for the year were about $460,000, or about $9.50 per ton. Net costs for the year were about $640,000, which translates to $13.20 per ton. Figure 2 shows the incoming tons and net facility cost by month for 1977.

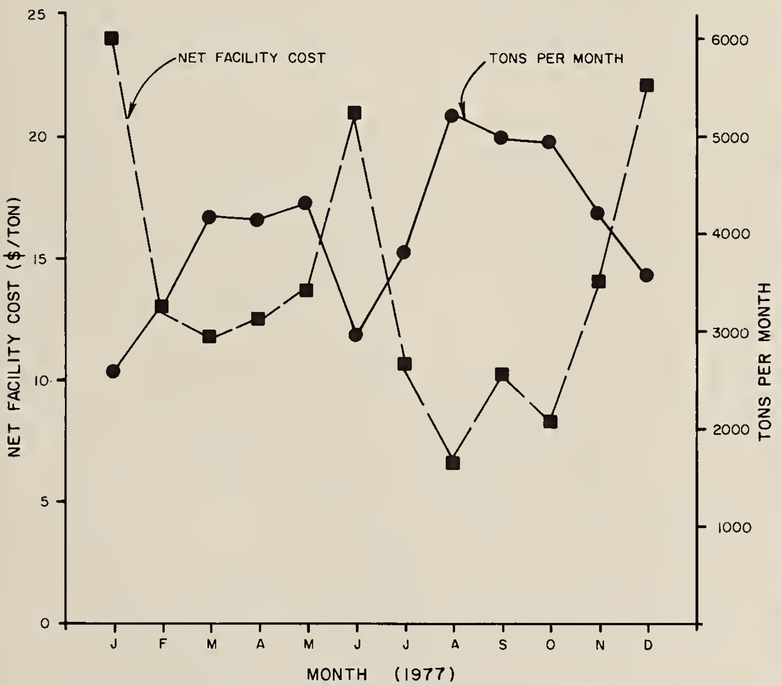

FIGURE 2. - Costs by month for 1977.

The Ames resource recovery system may be of interest to those starting resource recovery systems in other cities. With appropriate modifications, the Ames MIS could be used to monitor other supplemental fuel systems, processed-fuel steam systems, or mass-fired steam systems. The MIS provides a permanent record of the most important operating characteristics of a solid waste energy and materials recovery system along with various methods of data reporting.

The Ames solid waste recovery system has operated successfully and is presently in its third year of operation. Waste was diverted to the landfill for only 15 days during the year owing to scheduled and unscheduled downtime of the processing plant and the powerplant (an availability of over 94 pct). Although higher than landfilling costs in the region, the costs of the system have been showing a downward trend. The cost per capita for operating the system during 1977 was about $10. After the 1979 operating year, the startup costs will have been repaid. The 1980 operating year will show a net cost decrease of about $2 per ton for this reason alone.

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TROMMEL PROCESSING OF MUNICIPAL SOLID WASTE PRIOR TO SHREDDING

by

J. F. Bernheisel,[1] P. M. Bagalman,[2] and W. S. Parker[3]

Shredding has been traditionally regarded as the first step in processing municipal solid waste (MSW) for recovery of materials and energy. The facilities constructed in the last decade have generally taken this approach. The functions the shredder performs are two: (1) Reduction of material to a more uniform particle size, and (2) liberation of composites or entrapped materials.

There are, however, drawbacks to shredding. First, shredders have high operating and maintenance costs. These are primarily electrical energy consumption and the labor, energy, and materials associated with hammer retipping, balancing, and replacement. Further, shredding has deleterious effects upon subsequent resource recovery processes. Following shredding, the most common processing step is air classification. The idealized function of this is to produce two fractions: (1) An organic combustible fraction, and (2) an inorganic noncombustible fraction which can be processed for materials recovery. If the ideal were achieved, many of our current problems in resource recovery would be eliminated. However, the separation is far from ideal. Inorganic material reports with the organic fraction. The primary offender is glass and other fine-particle material. Some fine material is inherent in the solid waste; however, the greatest percentage is generated by the shredding process. The National Center for Resource Recovery has estimated that as much as 80 pct of the glass in MSW entering a shredder will be pulverized so as to fly in the air classifier. This, plus the fines inherent in MSW and the 8 to 10 pct ash of paper and wood products, results in a refuse-derived fuel (RDF) with an ash of 25 pct or better. In addition, the glass that misreports in the air classifier is lost to recovery if glass recovery is to be attempted.

To overcome the disadvantages discussed above, the design of the Recovery 1 facility in New Orleans--a partnership among the National Center for Resource Recovery, the City of New Orleans, and Waste Management, Inc.--incorporated a trommel screen. This device, placed prior to the shredder, opens the refuse bags, both paper and plastic, breaks glass and other friable materials, and removes from the MSW those items that are smaller than the nominal screen size. In New Orleans, this is 4 inches.

From the data developed by the testing in New Orleans, it can be concluded that the trommel achieves two of its design goals. It concentrates metals and glass for material recovery, and it enhances the quality of the potential refuse-derived fuel fraction. While there is a loss of potential fuel to the trommel underflow, it would appear that this would be acceptable in the many situations where lowering of the ash content is currently the primary concern. Further, the organics in the underflow are not lost and can be recovered by subsequent processing of the underflow for materials recovery. In conclusion, the trommel appears to be a valuable new tool in the effort to recover resources from municipal solid waste.

[1]Testing program engineer.
[2]Demonstrator program manager.
[3]Directing engineer.
All of the authors are with the National Center for Resource Recovery, Inc., Washington, D.C.

UPGRADING PRODUCTS FROM RAW REFUSE FOR MARKETING

by

M. M. Cavanna,[1] J. S. Almarez,[1]
F. P. Christobal,[1] and H. G. Ramirez[1]

Research on recycling urban solid wastes in Spain is being performed by the Empresa Nacional Adaro de Investigaciones Mineras, S.A. (ENADIMSA) in Madrid. This firm belongs to the Instituto Nacional de Industria (INI), which is a division of the Ministry of Industry of Spain. ENADIMSA is mainly concerned with applied research in geology, hydrogeology, mining, and mineral dressing problems, as well as in environmental control, especially in regard to the recovery of raw materials from urban and industrial wastes.

ENADIMSA's research on raw refuse was started 5 years ago, under the Plan for Scientific and Technical Cooperation between Spain and the United States.[2] Very effective aid was obtained from the U.S. Department of the Interior, Bureau of Mines, Avondale (Md.) Metallurgy Research Center. The latter provided all the information and experience it had accumulated at that time.

Research programs developed by ENADIMSA since that time have been conducted along the following three different lines of technology:

1. Rough classification processes, figure 1.

2. Upgrading operations, figure 2.

3. Utilization of organic materials, figure 3.

The work done on rough classification processes has been described in papers presented at the Fourth and Fifth Mineral Waste Utilization Symposiums and will not be further discussed here. The present paper describes details of the development of the next two lines of technology which complement the basic flowsheet previously exhibited for the rough classification process.

[1]All of the authors are with Empresa Nacional Adaro de Investigaciones Mineras, S.A., Madrid, Spain.

[2]A cooperative research agreement administered through the National Science Foundation and the Instituto Nacional de Industria.

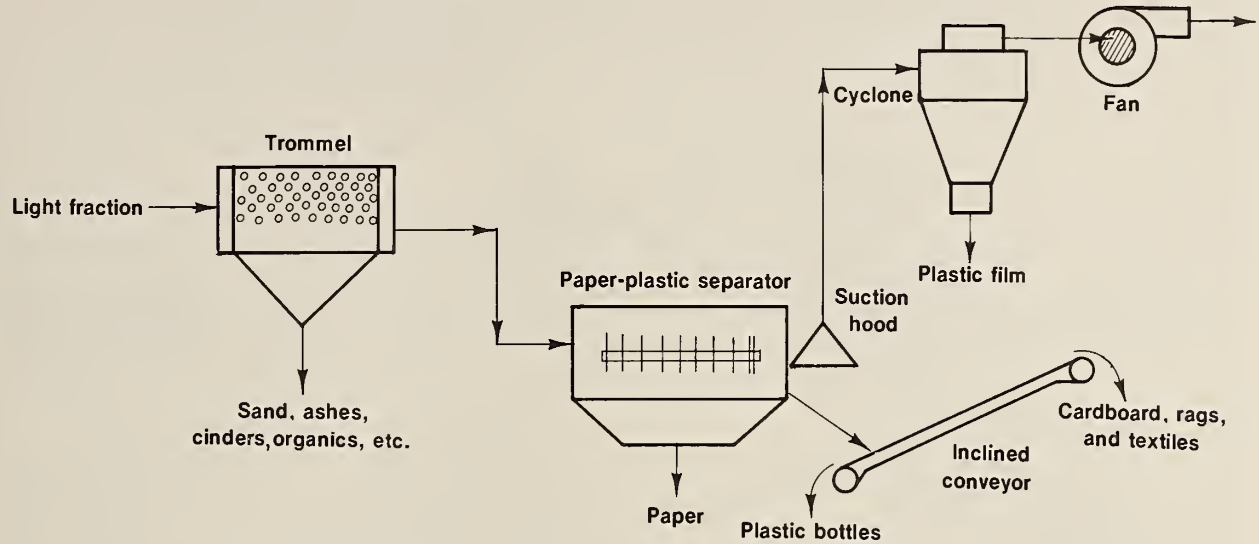

FIGURE 1. - Light-fraction upgrading process.

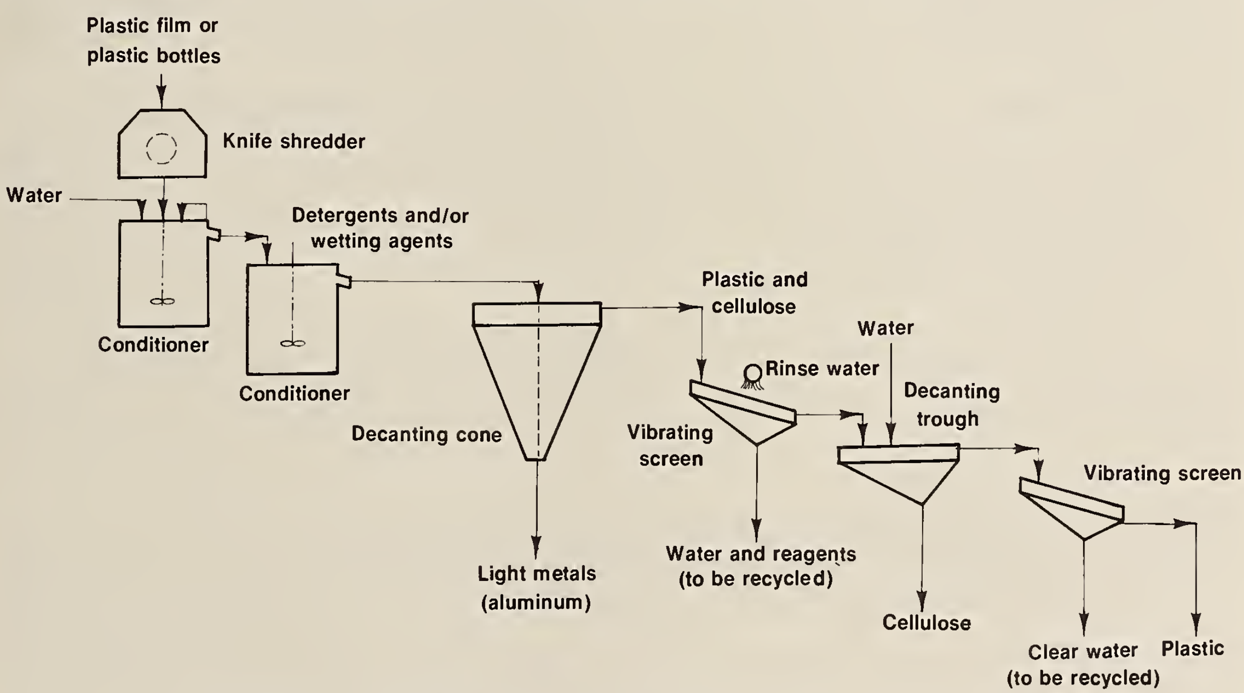

FIGURE 2. - Flowsheet for final cleaning of plastic film or bottles.

Products emerging from the rough classification process described in references 1 and 2 can be utilized commercially. However, the market prices for such products are very low. On the other hand, the price may be increased by means of simple upgrading or finishing operations, which is justification for the needed research in this area. This is illustrated by the following process developments:

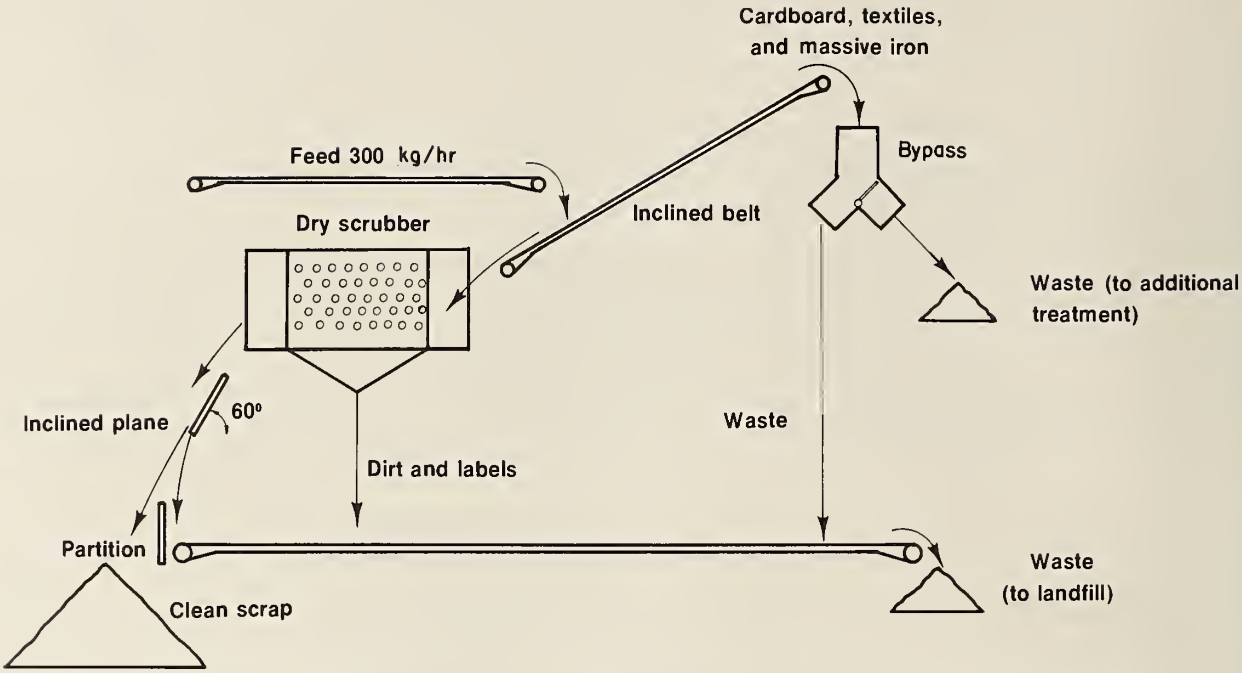

FIGURE 3. - Flowsheet for upgrading the ferrous product prior to detinning.

1. Paper from plastic separation.
2. Plastic upgrading.
3. Upgrading magnetic scrap.

The enormous quantities of food wastes, which may amount to as much as 60 pct of the total refuse in Spain, support the need for research on the utilization of organic materials. This involves new research in the following specific areas:

1. Energy production:
    a. Bioconversion (anaerobic biodegradation).
    b. Solid refuse-derived fuel (RDF) production.
2. Animal food production: Protein sources.

Most of the work on utilization of organic materials is still in a preliminary stage.

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UTILIZING PROCESSED INCINERATOR RESIDUE AS COVER MATERIAL FOR SANITARY LANDFILL

by

R. E. Cummings[1]

The City of Philadelphia has for more than 50 years employed incineration in its solid waste management program to reduce the volume of waste materials prior to land disposal. In recent years, the incinerator program has involved two modern combustion facilities, employing the best available technology and fitted with electrostatic precipitators for air pollution control.

Historically, the residuals resulting from these two facilities have been disposed of at land sites primarily within the City of Philadelphia. Continued use of sites within the city grows increasingly unlikely since such sites have all but disappeared. In addition, plans underway by the city envision at least one, if not more, energy recovery facilities utilizing solid waste as fuel. The end products of such combustion processes would be additional residue materials requiring land disposal. With diminishing acreages of disposal areas, it is clear that the energy plants of the future may be jeopardized by a lack of residue-disposal capacity.

The residue quantity from the two incinerator facilities is approximately 400 tons per day. At the city's Northwest Incinerator facility, residue from both plants was stockpiled for periods of up to one year prior to removal to land disposal sites. The residue was magnetically picked by a salvage operator under contract to the city to reclaim ferrous metal. It was felt that the combination of long-term storage and metal recovery altered the basic characteristics of this material--providing the opportunity for it to be considered as cover in sanitary landfill operations.

In order to achieve the purpose of this program, the parties--

1. Placed 400 tons per day of incinerator residue in a suitable holding area at the Northwest Incinerator facility for a period of 6 to 8 weeks.

2. Following suitable processing, removed this stored material from the holding area at a rate up to 300 tons per day to the Montgomery County Sanitary Landfill Site. The movement of this residue material utilized city personnel and vehicles initially. Currently, a single contractor processes and hauls the material to Montgomery County.

3. Utilized this material as daily and intermediate cover for the refuse disposed of in the Montgomery County Sanitary Landfill Site in a manner intended to duplicate as closely as possible the daily operating procedures currently employed at this disposal site. Some of the material was used for internal landfill roads and for testing as a final cover substitute.

4. Monitored, tested, and evaluated the effects of the use of this residue as cover on the landfill operations, including observations of the residue as cover. Techniques were utilized that were designed to determine if the residue satisfies the physical requirements of suitability for cover, wrokability, prevention of rodents and other vectors, and containment of combustion within a cell.

[1]The author is with Russell E. Cummings and Associates, Philadelphia, Pa.

The performance of the processed residue in its role as earth replacement for cover has been observed, monitored, and evaluated continuously since the inception of the shipments. Although more specific detailed evaluations are underway by Villanova University and the Department of Environmental Resources, the following observations can be made regarding criteria for suitable landfill cover:

1. Workability. Landfill operating personnel verify independent observations that the processed residue has comparable workability to loose soil. It was spreadable and compactible, and covered the refuse adequately to meet State requirements. A particularly dramatic benefit of the material was its performance under wet weather conditions. According to Villanova, the residue did not soften when wet, owing to its granular, relatively cohesionless nature. This fact extended the landfill's operations under adverse conditions.

2. Prevention of rodents and other vectors. No evidence of rodents or other vectors was observed as a result of the use of processed residue as soil cover replacement for the landfill. Additional monitoring of this fact is being conducted by county and State vector personnel. The material did not dry and crack so as to allow development of emergence of vectors.

3. Containment of combustion in a cell. No fires have occurred during the demonstration period, and experienced observers foresee no increased chance of uncontrolled fire based on this material as compared to soil.

4. Control of blowing paper. The processed residue performed the same role as normal earth cover in preventing the emergence of paper and litter through the cover. Had the material settled through the refuse due to an overly granular nature, problems of blowing paper would have occurred.

5. Suitability for revegetation. To evaluate the revegetative capabilities of the processed residue, a special testing program was established at the landfill and in the greenhouse at the consultant's labs. The primary purpose of the first tests was focused on the ability of the material to support and maintain grass growth. The processed residue combined with sewage sludge produced 3 to 5 inches of grass in thick quantities within 2 months. This growth reemerged in March and April 1978.

For a landfill that must use imported over, such as the one operated by Montgomery County, the possibility of cost savings can become reality. For example, the county pays $1.65 per cubic yard for its cover. At the projected rate of 300 tons per day, the value of the processed material can be as much as $155,000 per year. At the average rate of refuse receipts at the landfill, this would be equivalent to approximately $1 per ton.

The City of Philadelphia benefits by eliminating the haul of the material to current New Jersey landfills. The mileage saved is about 30 miles. Even if the haul were the same to an alternate landfill, the city could project a value equal to the price of disposal in comparable Pennsylvania landfills. For example, based on the Montgomery County disposal price of $7 per ton, the processed material turns a $650,000 liability into an equally valuable asset.

SOLID WASTE CHARACTERIZATION FOR RESOURCE RECOVERY DESIGN

by

J. P. Woodyard[1] and A. J. Klee[2]

Solid waste characterization, as defined here, refers to the estimation of the quantity and composition of solid waste available to a resource recovery system. Because exact information cannot be obtained, an acceptable level of estimate accuracy must first be identified in order to define the scope of the waste survey. Investors, designers, and markets may all specify an accuracy requirement; it is then left to the survey planners to decide how that level of accuracy can best be obtained.

<u>Accuracy versus Precision</u>.--The terms "accuracy" and "precision" are often used interchangeably but have entirely different meanings when describing a waste quantity or composition estimate. Accuracy refers to the closeness of an estimated value to the true value of the parameter being measured; precision refers to the repeatability of the measurements. To illustrate the subtle but important difference, imagine that an engineer is responsible for estimating the daily waste generation rate in City X. A review of the literature results in 10 per capita waste generation estimates that are close to one another in magnitude. Concurrently, random selection of 10 collection routes with known daily waste loading and population results in 10 widely scattered per capita estimates. The 10 literature estimates provide a more precise estimate of waste generation, while the 10 field measurements will likely provide a more accurate estimate of the true waste generation rate (assuming the route selection was truly random). In fact, only a well-designed field survey can provide an a priori estimate of the expected accuracy of the results.

Precision (and accuracy) is expressed as a percentage interval about the estimated mean (for example, ±10 pct). Because the size of the interval will be a function of sample number, accuracy requirements will actually dictate the level of effort necessary to properly perform the survey. This requirement is usually comprised, if not totally neglected, when the waste characterization budget is insufficient. As a result, past practice in waste characterization would not be expected to reflect the actual needs of resource recovery planners.

<u>Waste Characterization Accuracy Requirements</u>.--To determine the waste characterization accuracy required by the resource recovery community, quantitative accuracy requirements were solicited from designers and secondary material buyers. The sensitivity of system economics to inaccurate waste characterization was assessed through computer simulation.

[1]Project manager, SCS Engineers, Long Beach, Calif.
[2]Chief, Processing Branch, U.S. Environmental Protection Agency, Cincinnati, Ohio.

Design Requirements.--Design accuracy requirements are specific to each unit operation in solid waste processing (that is, receiving and storage, handling, shredding, classification, screening, magnetic separation, and thermal processing). These requirements were provided by the E-38 Committee of the American Society for Testing and Materials (ASTM) and are summarized in table 1. Supplemental data on design accuracy requirements were also obtained from (1) size-reduction equipment designers and operators, (2) incinerator operators, and (3) consultants experienced in resource recovery design.

TABLE 1. - Waste characterization accuracy requirements

Unit operation	Precision, pct[1]	Parameters
Quantity estimation:		
Receiving, storage..........	±10-20	Tons per day.
Shredding..................	±10-20	Tons per unit time.
Handling....................	±10-20	Do.
Classification..............	±10	Do.
Screening..................	±10-20	Do.
Magnetic separation.........	±20-50	Do.
Thermal processing..........	±10-20	Do.
	Critical waste components	Design sensitivity
Composition estimation:		
Receiving, storage..........	OBW............	Low.
Shredding..................	OBW, Demo......	Medium.
Handling....................	OBW, Demo......	Do.
Classification..............	All............	Do.
Screening..................	Glass, garbage.	Medium--low.
Magnetic separation.........	Metals.........	Medium.
Thermal processing..........	Organics.......	Medium--high.

Demo Demolition waste. OBW Oversized bulky waste.
[1]Represents mode of responses; range in most cases was up to ±100 pct.

The findings indicate that both quantity and composition accuracy requirements for resource recovery design vary with each unit operation. ASTM reported accuracy requirements for quantity estimation that were as stringent as ±10 pct. Requirements for composition estimation appeared less critical and were based on the identification of specific components in the waste stream. Each unit operation tended to be sensitive to one or more components. Less stringent design accuracy requirements were reported by processing designers, manufacturers, facility operators, and consultants. These requirements were generally based on the literature and incorporated some degree of conservative design.

The diversity of responses indicates that design accuracy requirements have been specific to each designer. No industry standards exists. The ±10 to 20 pct precision figure was subsequently used as a target specification for developing the statistical survey design but should be interpreted only as a worst case specification for experimental work.

Marketing Requirements.--Accuracy requirements are an important consideration in the marketing of materials and energy recovered from solid waste. High-technology systems may generate more material than low-technology systems in the same waste shed. To develop the stable market conditions necessary for this larger amount of material, investors require long-term contracts for the sale of recovered materials. Before signing such contracts, buyers will often require that the quantity and quality of material to be sold be specified with a certain degree of accuracy. Price is sometimes determined based on expected volume, and penalties for inaccurate estimation have been incorporated in some contracts.

Reporting of Results.--The reporting format and level of detail desired may be specified by the ultimate uses of the survey data. If not, the results should be reported in summary form with a brief review of the procedure used (assumptions, data sources, etc.). The following general guidelines of what not to report are also offered:

1. Do not report quantity or composition data by route or hauler, if possible, as many haulers feel this information is confidential.

2. Do not report the results of the survey without some description of the survey procedure used. Others may use the data later and should know its limitations.

3. Do not report the data without the computed confidence intervals; interpretation of the estimate should be left to the user of these estimates.

4. When using published data in place of part or all of the survey, reference it as such and do not publish it again as "local" data. This only serves to perpetuate data that may be outdated or of questionable origin.

The characterization of solid waste is typically a low-priority item in resource recovery design. Designers and markets are beginning to develop more stringent accuracy requirements, thereby necessitating the use of field surveys to satisfy these requirements. Through statistical design, these surveys can be performed for a reasonable cost. Field surveys should be more widely used in place of published estimates.

MARYLAND ENVIRONMENTAL SERVICE-BALTIMORE COUNTY RESOURCE RECOVERY FACILITY, TEXAS, MD.

by

C. R. Willey[1] and M. Bassin[2]

In 1970, the State of Maryland created an agency, the Maryland Environmental Service (MES), one of the first of its kind in the Nation, to provide planning and utility services for sewage, water supply, and solid waste management to counties, municipalities, and industry. MES now operates 56 sewage treatment plants, a 60-ton-per-day compost plant which converts sludge to solid compost for agricultural use, a 100-ton-per-day sludge dehydration project, and a sludge trenching project averaging 270 tons per day and oversees the operation of the Baltimore County Resource Recovery Facility. Included in MES' plans for the future are a 240-ton-per-day sludge recycling plant, operation of additional sewage and water treatment plants, and other resource and energy recovery systems for municipal solid wastes.

In 1972, MES began investigating possible designs for a Maryland reclamation project. Concurrently, Baltimore County initiated studies to identify alternate disposal methods and/or locations for a refuse disposal facility in the county. The limited life of the Texas Sanitary Landfill near Cockeysville, Md., dictated that other means for northern Baltimore County solid waste disposal would have to be provided. Accordingly, MES and Baltimore County entered into a joint venture to create a resource recovery facility to serve the northern county.

Teledyne National was selected as prime contractor and system integrator for the associated marketing, facility design, construction supervision, and operation. A parcel of land was selected at the Texas Sanitary Landfill and in August 1974 site preparation was begun.

In this paper, an overview of the project will be presented with emphasis upon unique features, especially associated market and product development. To maintain proper perspective, the separation and recovery processes and equipment will also be described.

The MES-Baltimore County Resource Recovery Facility (fig. 1) designed to process up to 1,500 tons per day, started operations in January 1976. Early on, four separate stages were planned:

1. A transfer and shredding facility with ferrous metals being recovered and sold.

2. A system for producing refuse-derived fuel (RDF) and selling it.

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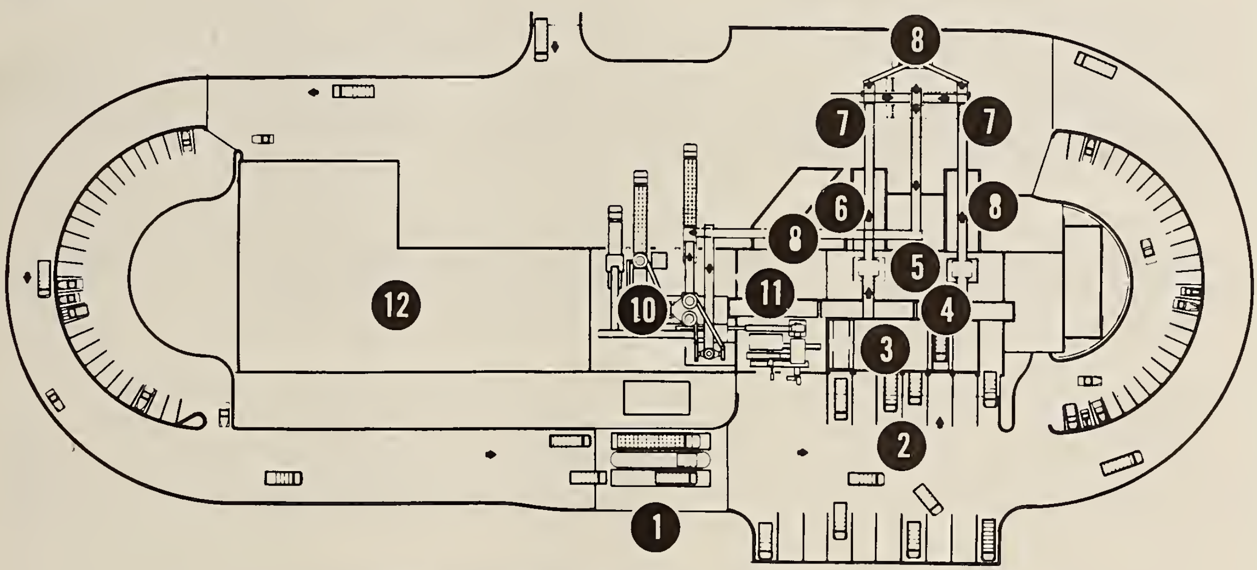
[2]Director, product planning, Teledyne National, Northridge, Calif.

3. Full-scale tests and demonstrations for recovery of glass and non-ferrous metals.

4. Full-scale operations.

The system for resource recovery features dry separation and recovery in a basically modular, redundant design to provide maximum reliability and flexibility in terms of growth and technological advancements. An average of about 400 to 500 tons per day of municipal solid waste (MSW) has been received and processed at the resource recovery facility since the start of operations. When the new southwest Baltimore County transfer station goes onstream in the spring of 1978, the quantity of MSW delivered to the facility is expected to double.

Trucks enter the resource recovery facility in a one-way pattern and proceed to an automated weigh station and then to the staging and unloading areas.



1. AUTOMATED WEIGH STATION
2. STAGING AREA
3. OVERFLOW PIT
4. SHREDDER INPUT SYSTEM
5. SHREDDER
6. SHREDDER OUTPUT SYSTEMS
7. FERROUS SEPARATION
8. LOADING TOWER
9. FUEL PROCESSING INPUT SYSTEM
10. FUEL PROCESSING AREA
11. SECONDARY SEPARATION AND RECOVERY AREA
12. PRODUCT MANUFACTURE – FUTURE

FIGURE 1. - Schematic flow chart of Maryland Environmental Service–Baltimore County resource recovery facility.

The MES/Baltimore County Resource Recovery Project, employing relatively low-risk dry separation and recovery processes and equipment, will provide light fraction for sales as RDF, for sludge treatment, or for building materials depending upon changes in refuse composition, existing markets, and the associated economics.

The RDF burn program in the boiler of a large paper company has been completed. The paper company is now considering the use of RDF for its future energy requirements. RDF tests in a lightweight aggregate kiln were successful at conservative Btu replacement ratios of 70 pct RDF to 30 pct coal.

A burn program with the participation of the EPA is scheduled this year in a cement kiln.

Additional light fraction will be supplied for composting with sewage sludge at the U.S. Agricultural Research Station in Beltsville, Md.

Glass products, specifically GPC pipe, foamed glass insulation, and lightweight aggregate, have been developed to production readiness.

Ferrous is being sold to a steel manufacturer; a contract for the sale of aluminum will be finalized this year. Several companies have expressed an interest in recovered mixed nonferrous.

The impact of additional MSW from the new transfer station on economy of scale, the continued development of RDF markets, and the sale of aluminum will provide the basis for economic evaluation of this project.

IMPACT--PAPER RECYCLING VERSUS SUPPLEMENTAL FUEL

by

H. J. Perry[1]

Although at present there are only a few scattered energy plants that use municipal solid waste as a supplementary fuel, it appears that the trend is upward as landfill sites become increasingly scarce. Certainly this use of trash is ecologically sound. However, there are increasing signs of concern over the possible loss of waste paper from the historical recycling pattern into paperboard, construction paper, and the board industry. In addition, the relatively new industry of recycling old newspapers back into newsprint can be affected because it is largely dependent upon the metropolitan areas for its raw material and these areas are the most likely to use trash for supplemental fuel.

Numerous studies indicate that the United States may be faced with a wood shortage anywhere from 1990 to 2025. Certainly, it is becoming more difficult to increase the wood supply in view of future legislation, court decisions, emotions, and environmental concerns, real or imagined. Thus, it seems wise at this time to consider the effects of burning of cellulose fiber and building long-life systems for its destruction as fiber.

While it is uncertain at this time to project the increasing demand for waste paper very far into the future because of the complicated economic problems of reuse, now is the time to give the problems considerable thought.

We seem to be faced with two major questions. Do we restrict the collection of waste paper in our municipalities for recycling back into the paperboard industry or reserve it for steam generation, or do we use steam generation as a secondary system to consume waste paper where the supply exceeds the demand?

In the first case, this situation has occurred in the Saugus, Mass., area wherein all municipal solid waste is reserved by municipal ordinances for steam generation. This action has upset the local sources of supply of old newspapers and old corrugated cartons normally used by the local board mills. It appears to have had serious economic consequences. In the second case, it is the normal historical pattern of disposal or recycling. As waste paper exceeds demand, more is landfilled or incinerated.

Thus, we come to another important question--how much effect does increased consumption of waste paper have on the calorific value of municipal solid waste? There is little change in Btu values under the various assumed conditions under study. On the dry basis, 8,000 Btu per pound seems to be a fair value. On the wet basis, 24.5 pct moisture, which is the basis of feeding the steam generators, the fair heat value is 6,000 Btu. No consideration

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has been given to some noncombustible carryover in a shredding and air classification. The ash content is likely to vary in the various components. So, 5,000 Btu as used in many estimates is a conservative value.

A potential decline of waste paper in municipal solid waste has several environmental consequences--less collected tonnage by municipal authorities and more concentration of noncombustibles at a processing plant. It seems to justify separation operations because of sizable volume of glass and metals. If cullet can be sorted by color as research indicates, a market can be developed for glass. Therefore, so far as the facts are known, the collection of waste paper for recycling will not change the supplemental fuel heat value. It is, therefore, unnecessary for municipal authorities to impose restrictions on the collection of waste paper for recycling unless the decline in volume makes steam generation unwarranted, a condition that seems unlikely. Lowering the volume of waste paper by various collection systems will actually be beneficial by lowering trash collection costs for municipalities.

As important as reduction in collection of trash is to a municipality in reducing costs, a major reduction by salvage at the curb level could reduce the quantity to the point where it could affect the profitability of a plant designed to use trash as a primary fuel. It would seem wise therefore to consider trash as a secondary fuel because it is unlikely that minimum quantities of trash would balance with minimum steam or energy demands.

NEW RECLAIMING PROCESS FOR WASTE PAPERS

by

K. Saitoh,[1] N. Mishijima,[1] and A. Kimura[1]

At present Japanese paper production amounts to 15.4 million tons per year, and 6.3 million tons of them are recovered and recycled as waste paper. The 38 pct reclaiming rate (1) is twice as high as that of the United States and will probably increase to 50 pct in the near future owing to a lack of timber resources.

From the standpoint of material and energy savings, recently there have been strong demands for the development of new processing techniques for waste papers. Conventional reclaiming processes for waste papers have many problems; for example, too high consumptions of water and electricity, clarification of waste water, disposal of sludge produced from the thickener, and high operation costs. Research was conducted on the processing of printed waste papers which contain large quantities of ink and clay. As a result, a new reclaiming process was developed.

The process itself has a number of advantages and has been greatly simplified and improved. It also yields great savings in terms of overall operating costs. Patent applications for this new system have been made in Japan and abroad. Printed waste papers are processed in the following steps: Disintegration, ink flotation, fiber recovery from deinked pulp, and clay flotation in waste water.

In disintegration, waste papers are fed into a hydropulper where they are pulpified and contaminants are removed from the paper fiber by using alkali and sodium silicate to promote defiberization. The disintegrated pulp is fed into an ink flotation cell where small air bubbles are generated uniformly from the cell bottom where air is blown into specially equipped porous bodies. Ink flotation is promoted by adding surface-active agents, such as petroleum group agents, oleic acid, and pine oil. In the next step, fibers are recovered as oversize from the deinked pulp by using a vibrating screen. White waste water through the screen containing large amounts of fine clay is supplied to a clay flotation tower. Then the flocs readily float, adhering to the air bubbles. The vertical flotation cell is also available for clay flotation. Recovered clay containing high-quality kaolinite can be supplied as refractory materials and as various fillers after calcination. Since the clay flotation efficiency is very high and the effluent from the process is very clean, it is possible not only to discharge the effluent but also to reuse it again.

Although the reclaiming rate of waste paper in Japan is increasing yearly, the effluent and sludge discharged from reclaiming plants are being regulated continuously in terms of pollution control. Consequently, reclaiming plants for waste paper have to have not only low operation, but also a clean system free of harmful discharges.

The new reclaiming system features a unique process with equipment specially designed to meet the current demands. As the world supply of natural resources diminishes, the need for reclaiming and utilizing waste papers becomes more and more urgent.

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[1]All of the authors are with the Central Research Laboratory, Mitsui Mining & Smelting Co., Ltd., Tokyo, Japan.

INDUSTRIAL WASTES

RECYCLING SCRAP--A DECADE OF CHALLENGES AND FRUSTRATIONS

by

H. Ness[1]

We all know that recycling conserves material resources, reduces solid waste disposal, and conserves energy. At the beginning of this decade, there seemed to be some doubt of how effective recycling really is. Therefore, different Government agencies prepared extensive reports and surveys to gage its impact and effectiveness. Now, after 10 years of official scrutinizing and analysis, we know much more about recycling's values and potentials. We can pinpoint how much energy can be saved, we can pinpoint the conservation of natural resources, and we can pinpoint how much we can reduce the size of our growing solid waste load.

That is what we have been able to accomplish in these last 10 years. Unfortunately, however, none of this has actually resulted in measurable increase in the recycling of metallics and other materials. To the contrary, all of the favorable surveys aside, recycling is very much what it was a decade ago. We have come far in understanding the need for recycling but not in accelerating recycling in any measurable degree.

On figures 1-6 the recycled commodities are plotted versus their virgin counterparts for the period from 1968 to 1977. Looking at each commodity, we can get a picture of what has happened in the last decade.

Aluminum.--Secondary aluminum shows a slight but steady increase for this period. Primary production of aluminum except for 1975 shows a more rapid rate of increase than secondary. With the amount of publicity and effort that has gone into recycling of aluminum during this period, one would expect a better performance of secondary than is indicated here.

Copper.--The spread between "purchased copper scrap" and "refined copper" increased during most of this period. It is readily apparent by looking at figure 2 that recycled copper lost ground almost every year.

Iron and Steel.--Purchased iron and steel scrap follows almost the identical path that steel production takes, only on a lesser scale. Here, too, one would have expected--because of the publicity and exposure--scrap to increase at a greater rate.

Lead.--Secondary lead is the only commodity of those considered here that gains a little each year as compared with its virgin counterpart. Battery

[1]Technical director, National Association of Recycling Industries, Inc., New York, N.Y.

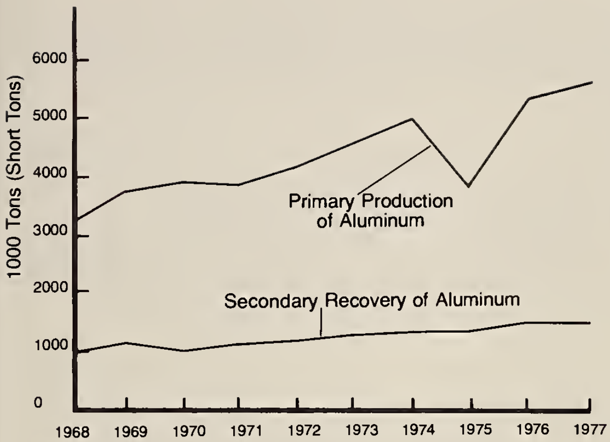

FIGURE 1. - Aluminum. (Courtesy U.S. Bureau of Mines.)

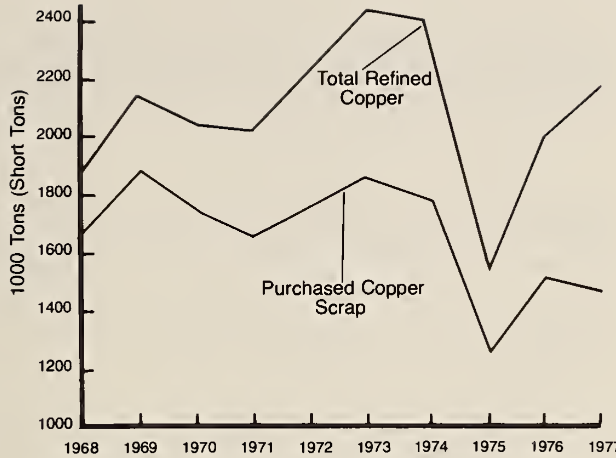

FIGURE 2. - Copper. (Courtesy U.S. Bureau of Mines.)

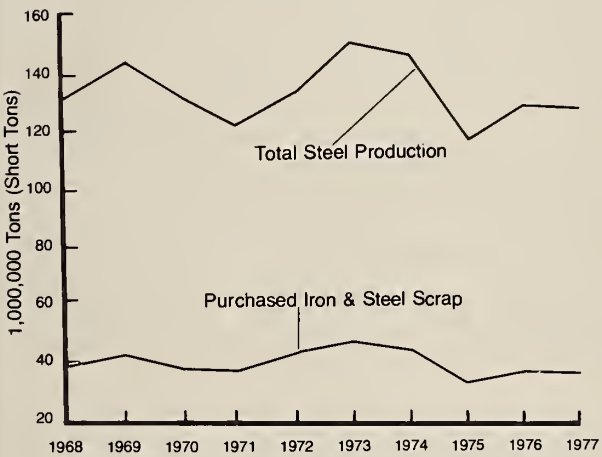

FIGURE 3. - Iron and steel.

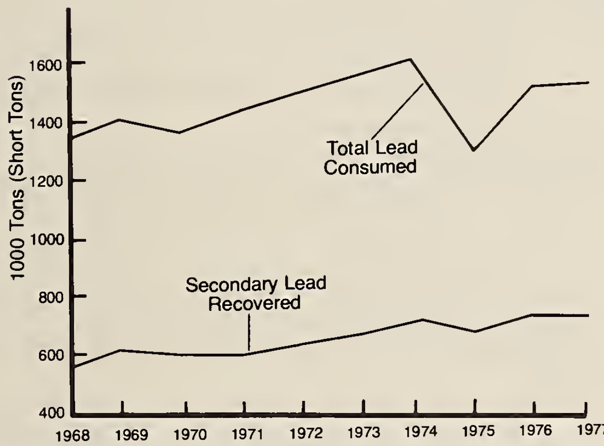

FIGURE 4. - Lead. (Courtesy U.S. Bureau of Mines.)

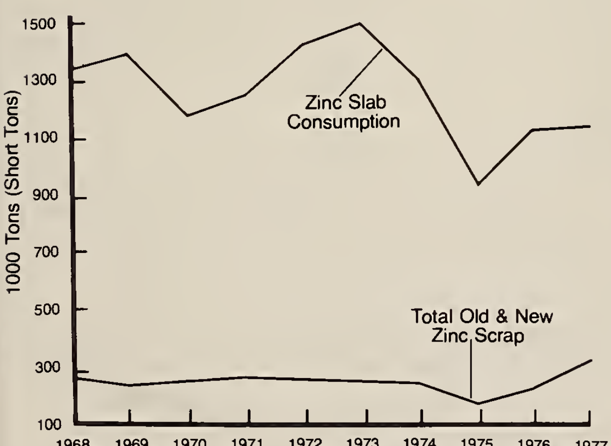

FIGURE 5. - Zinc. (Courtesy U.S. Bureau of Mines.)

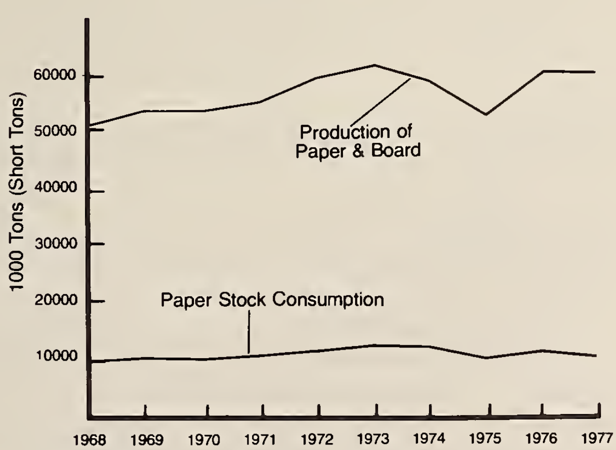

FIGURE 6. - Paper. (Courtesy U.S. Department of Commerce, Bureau of Domestic Commerce.)

recovery accounts for the greatest part of secondary lead recovered. The fact that usually one returns a used battery when purchasing a new one helps keep the amount of secondary lead recovered high.

Zinc.--The amount of zinc scrap recovered in comparison with zinc consumption is low to begin with, and through the years, continues to decrease. The recovery of zinc scrap does not keep pace with zinc slab consumption. Of course, one of the reasons that recovery is so small is that zinc is used in and on products as coatings and pigments, and these are not easily recoverable. However, this does not explain why zinc scrap does not keep up with zinc consumption.

Paper.--To most environmentalists--and to many in the industry--paper stock consumption has been one of the biggest disappointments in all the recycled commodities. Paper stock consumption has not kept pace with the production of paper and board. In addition, the rate of recovery is still very low, approximately 20 pct. We know that this rate can be increased substantially. During World War II, U.S. recovery rates rose to over 35 pct. Other countries' paper recovery rates have gone up to 50 pct.

Certainly, the prime indicator of how we are doing in recycling of any particular commodity is the recycling share of the market. In point of fact, this indicator is the ratio of amount of recycled material recovered or used to the total amount of the material produced or consumed.

The recycling share of the market for each of the materials discussed is shown in table 1 for 1968 and 1977. Aluminum shows an increase, but of only 1 pct for the entire decade. Lead is up from 42 pct to 47 pct. All of the remainder are either the same (iron and steel) or down (copper, zinc, and paper).

TABLE 1. - Recycling share of market, pct

	1968	1977
Aluminum	23	24
Copper	45	40
Iron and steel	30	30
Lead	42	47
Zinc	21	13
Paper	20	17

These figures and charts represent a frustrating and disappointing story for recycling. They show very little change in the true recycling picture for the last 10 years.

Recycling will occur only when economic conditions justify it. In recycling, as in any other major industry in America, the profit motive is a prime factor. Supply and demand must be balanced. If there is an oversupply of material, demand retracts and prices spiral downward, reducing the incentive on an industrywide base to collect and process recoverable material.

Why isn't more material recycled? What must be done to enable recycling to expand--to move material from the solid waste pile to the resource supply? Where are the present bottlenecks? In order to expand recycling, the most critical need is markets. Our direction sign reads: Markets first, collections second.

In order that the recycling industry may work to its maximum potential in helping to solve the urgent problems of energy and resource conservation and solid waste disposal, the industry must have--

1. Expanded research, with emphasis on developing means of utilizing lower grade solid waste, including unsegregated materials and mixed refuse.

2. The development of new equipment and new techniques capable of processing recycled materials on a more economic basis.

3. Changes in tax policies to encourage and stimulate recycling, similar to those now accorded most other major industries.

4. Freight rates that are nondiscriminating, fair, and reasonable. These rates on recyclables are often double those placed on competing commodities.

5. The need for programs to create expanded markets for products containing recycled materials, with emphasis on eradicating discriminatory purchasing policies and irrational specifications.

6. The need for changes in onerous zoning, licensing, and other local operating regulations, which now inhibit the growth of the recycling industry.

7. The education of consumers--the purchasing public--as to the quality of products made with recycled materials and the intrinsic environmental values of purchasing such products.

These represent effective responses to some of the basic bottlenecks to recycling and the reasons why present available metals may go to the dumps instead of being utilized. These are all vital steps in helping to make recycling a truly viable force in our economic system.

Of the seven items listed, the first two--expanding research and developing new technology and equipment to economically recycle material--should be considered the major challenges.

Economical technology has to be researched and developed for new methods of taking low-grade metallic wastes and recovering the metal contents. It is only when the material that now goes to the dumps is economically salvaged that we will be able to show increased national recycling rates that will be truly meaningful.

WASTE MANAGEMENT STRATEGY FOR MAJOR INDUSTRIES

by

J. J. Emery[1] and D. B. Matchett[1]

Industrial waste management has acquired urgent significance because environmental pressures and regulations are growing at the very time when the necessary profitability to incur capital investments for combating pollution is being squeezed by increasing energy, raw materials, and labor costs. The control of gaseous and liquid emissions, solid waste handling and disposal, and special problems such as noise, vibration, heat pollution, and radiation all call for increasingly sophisticated and expensive equipment, often requiring more company resources than the actual production process involved (3). When it is considered that an estimated 270 million metric tons of industrial wastes are generated annually in the United States, with 10 pct classified as hazardous by the Environmental Protection Agency, the magnitude of the problem becomes clearer (2). Pollution control is big business, as reflected by the approximate $11 billion to be spent in the United States for control of air, water, and solid waste pollution during 1978; that is, almost 7 pct of all planned capital spending by business. The situation is similar in Canada for major industries.

The interrelationship between energy and pollution is being increasingly recognized, given the escalating cost of energy since 1973. Significant energy has often been invested in waste and byproducts during primary product production that is lost when simple disposal replaces recycling, recovery, or utilization. Waste should obviously be minimized at all stages of production, and any wastes produced should be recycled where possible to both conserve raw materials and reduce energy consumption (1). Energy accounting during waste management, while a simple concept, requires much more attention as part of an overall waste management strategy.

While the environment and energy have been important factors focusing attention on waste management, the problem of waste disposal is probably the critical factor for many industries. For plants in urban areas, the total cost of disposal (collecting, handling, transportation, dumping) to approved sites ranges from about $5 to $15 per metric ton. Further, municipal authorities are tending to limit the dumping of industrial wastes in landfill sites (that is, reserving capacity for domestic refuse) and are requiring major plants to develop their own disposal areas that must meet increasingly stringent environmental controls. Liquid and hazardous wastes require a much higher investment in acceptable disposal methods and sites, and a number of companies have entered this market to provide the necessary services, often at a substantial unit cost to meet a wide range of governmental regulations. A major activity is the solidification of sludges and liquid wastes by a number of proprietary processes.

[1]Both authors are with the Department of Civil Engineering Mechanics, Construction Materials Laboratory, McMaster University, Hamilton, Ontario, Canada.

Implicit in the above discussion of general waste management concepts is the question of how the necessary capital will be generated to combat industrial pollution and improve the environment. While it is clear that the public will not tolerate a decline in the environmental standards already attained, it is also clear that any reduction in standards of living through restricted plant operations, decreased growth, or even closure to meet these standards will not be popular. In general, the capital must come from the industry, with increased governmental support to combat pollution whenever required, and recognizing current financial constraints. It is considered that an integrated waste management strategy plays a key role here, as it can reduce both disposal costs and environmental pressures while contributing to the overall profitability essential for financing further pollution abatement. A waste management group with a well-developed strategy should form an element of corporate structure to focus on the problems and costs of waste disposal and to take advantage of potential savings.

Since the waste management strategy described here was developed as part of waste and byproduct utilization studies in the Construction Materials Laboratory, and by the Trow Group Limited Consulting Engineers, for the foundry, iron and steel, nonferrous, and cement industries, the emphasis is on solid wastes with general background information drawn from the iron and steel sector. However, the importance of including liquid and geseous emissions in the strategy is recognized, and some general concepts of energy accounting and waste are introduced here.

The key elements of the waste management strategy that have evolved are--

1. Determining the types, characteristics, and quantities of wastes and byproducts for each major process and/or product, including energy accounting. This should include both present and future waste generation, typically in terms of waste generation coefficients (waste per unit of product). Simple materials (and energy) balances for processes will often yield much improved estimates of waste quantities and the disposal problems involved.

2. Reducing the loss and/or degrading of materials and energy during processes. This aspect of a waste management strategy is described in the next section.

3. Encouraging recycling and/or recovery of wastes and byproducts where feasible in the plant, or in other industries that can use the byproduct.

4. Optimization of waste collection, handling, transportation, and disposal systems. This will require close cooperation of the production, utilities, transportation, and planning staffs involved.

5. Development of potential applications for wastes and byproducts. Must include a marketing strategy that reflects the technical and economic constraints involved. This is the subject of a companion paper and will not be covered here except to emphasize the importance of taking advantage of a waste's inherent energy and materials value in applications involving recoverable and replaceable energy, or special materials features. Waste materials exchanges offer a valuable method of making the necessary contacts.

6. Design of waste disposal sites and storage areas for materials that may have future recyclability or uses. Must be in terms of immediate and long-term regulations. While not a direct step, overall coordination and review of the waste management strategy by a waste management group with active senior level participation is required to ensure that the interacting objectives are met within the rather complex organizational framework of major industries. The major difficulty often appears to be the initial step--implementation--with the resulting savings providing the necessary impetus for further steps.

Although the framework for a suggested waste management strategy has been given, it is clear that each company must develop an individual strategy meeting its specific requirements. However, it is considered that a common feature throughout will be a recognition of the importance and interaction of pollution and energy. Based on the writers' experience in the Hamilton area, it is clear that a waste management strategy can make a positive contribution to company profitability and should form an aspect of overall corporate planning.

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IRON AND CARBON RECOVERY VIA THE RECLAFORM PROCESS

by

J. S. Young, Jr.[1]

The utilization of the Reclaform Process is indicated whenever a fines management situation arises where additional carbon units are desirable or at least innocuous. The carbonaceous binder system results in 80 to 90 pct of the initial binder weight reporting as carbon in the final agglomerate. Areas of application that have been evaluated or are underway include iron and steel fines management, foundry fuel, carbon silica composites for hot blast cupolas, dezincing and metallization or smelting of steelmaking fines, flux-metal fines composites, industrial charcoal agglomerates, and charge agglomerates for lime regeneration kilns.

With emphasis on carbon, projects dealing with furnace coke, foundry coke, and petroleum coke are aimed at better understanding of surface area, stability, reactivity, porosity, and chemistry effects. Efficient utilization of energy and carbon resources is the primary goal of this work.

A roll briquetter forms the Reclaform briquet at relatively low pressure without further fracturing of the particles being recovered. The binder surrounds these particles and is polymerized, resulting in a matrix rich in carbon-carbon bonds, which imparts the necessary strength for materials handling and furnace consumption. Since this binder system relies very little on the bound particles for its strength, it can be applied to a wide range of particulates.

Figure 1 outlines the Reclaform Process. Sized raw materials are blended and dried or preheated. Hot binder is injected into the mixture with close temperature control and mixed prior to feeding the roll briquetter. The green briquets are screened and fed to the curing oven, where precise temperature and air flows are controlled to polymerize the binder and result in a cured carbon matrix. Zoned curing temperatures range from 450° F (232° C) to 600° F (316° C). In curing, a controlled exothermic reaction occurs which signals polymerization. Time, temperature, gas flow, gas composition, briquet permeability, and the binder used are all important factors in the design and operation of the curing oven. Condensable hydrocarbons released during curing are incinerated with the heat recovered and used in the drying stage and the oven itself. After curing, briquets are discharged and ready for immediate consumption or storage as mill operations require. Storage presents no problem since the briquets do not require special handling or protection from the weather.

[1]Technical manager, Reclasource Corp., Chicago, Ill.

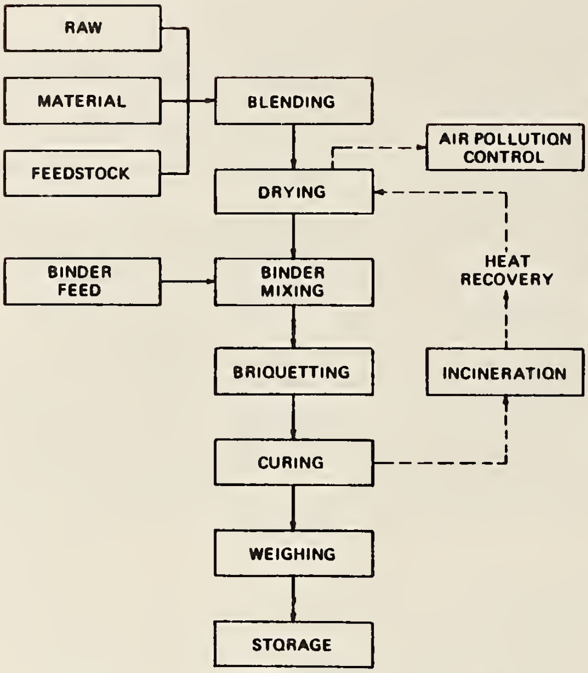

FIGURE 1. - Flow diagram of the Reclaform process.

A 10-ton-per-hour pilot plant was constructed and commissioned by Reclasource for the recovery of coke breeze, mill scale, blast furnace dust, blast furnace sludge, and basic oxygen furnace dust at the site of Crucible Alloy Division, Midland, Pa. The plant was field-engineered using for the most part available, known equipment. The major exception was the installation of an experimental curing oven which has provided information for the design of a full scale production oven. Figure 2 is the pilot plant layout diagram.

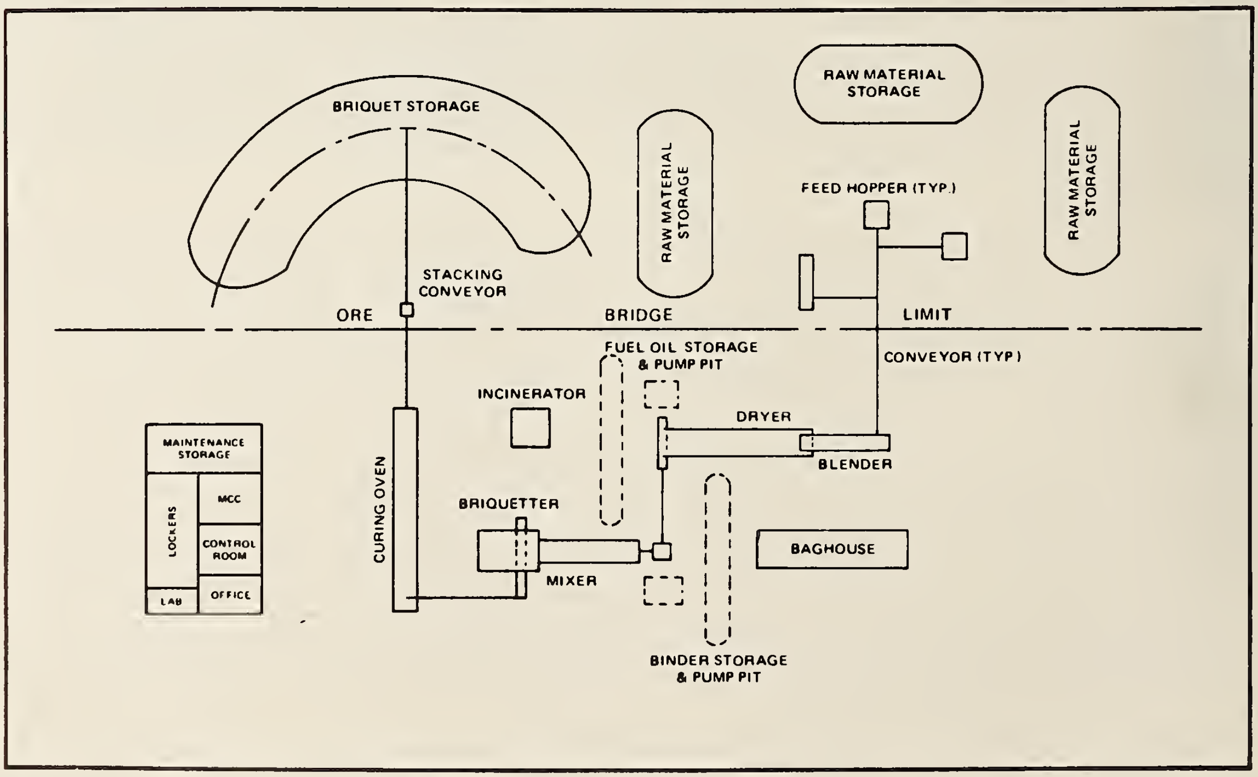

FIGURE 2. - Typical Reclaform plant layout.

RECOVERY OF ZINC OXIDE FROM GALVANIZING WASTES

by

J. B. Stephenson,[1] P. G. Barnard,[2]
and A. A. Cochran[3]

Importing approximately 50 pct of the zinc consumed in the United States has underscored the need to recover the metal from brass and bronze flue dusts, steel furnace dust, diecastings, sludges, and galvanizing wastes (4-7). The Bureau's Rolla Metallurgy Research Center has been investigating the recovery of zinc from a variety of wastes including those from galvanizing. Previous Bureau research resulted in a process for the recovery and reuse of sal skimmings for flux solutions (8). Dross can be treated in special liquidation furnaces to lower its iron content, or distilled to produce zinc dust or slab zinc (2). Zinc recovery from galvanizing ashes is difficult because the material is a complex mixture of oxides, metallic zinc, and chlorides.

Galvanizing wastes are zinc-bearing secondary domestic resources made up of dross, ashes, and sal skimming (1, 3). Zinc dross, a mixture of zinc-iron alloys, forms in galvanizing kettles or furnaces through the interaction of hot zinc with steel or iron. Sal skimmings are spent fluxes from cleaning steel prior to dipping in the molten zinc, and zinc ashes are the zinc oxide that forms at the molten zinc surface in the galvanizing kettle. Hot-dip galvanizing, with about 25 pct of the total galvanizing market, has average zinc losses of 22 pct dross, 12 pct flux, and 17 pct ashes. From other types of galvanizing, such as strip and sheet, the production of dross and skimmings ranges from 5 to 10 pct. The combined total of these zinc losses amounts to 80,000 to 120,000 tons per year (9). The recent closing of zinc smelters using the horizontal retort process greatly decreased the market for this type of zinc-bearing waste.

A chlorination process for galvanizing ashes, of immediate interest to industry, was developed on a laboratory scale. Lead levels of 0.25 pct could not be attained at 900° C with $CaCl_2$ as the chlorination agent. Chlorinating the galvanizing ashes with 2.5 pct $CaCl_2$ and 1 pct SiO_2 at 900° C for 1 hour consistently produced a zinc oxide product containing less than 0.25 pct lead that was suitable for metallurgical and chemical use. The zinc oxide product contained over 90 pct of the zinc present in the roasting feed; less than 10 pct of the total reaction mixture was volatilized. Reaction temperatures as low as 850° C may be used to produce a low-lead product by increasing the $CaCl_2$ and SiO_2 concentration to 4 and 2.5 pct, respectively. An equation for accurately predicting the effect of $CaCl_2$ and SiO_2 additions on chlorination results was developed for use in plant-scale tests.

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RECYCLING OF POTLINING IN THE PRIMARY ALUMINUM INDUSTRY

by

W. D. Balgord[1]

More than 20 years ago the Bureau of Mines recognized the importance of recovering critical materials from wastes in the manufacture of primary aluminum. Toward that end, it developed several flotation and leaching processes to recover fluoride values from spent potlining residues in the form of cryolite and other materials (1, 4-5).

Although several aluminum companies have reclaimed cryolite from potlinings for a number of years, solid waste management on the whole continues to present the industry with two challenges: how to minimize the environmental impacts of its manufacturing processes, and how to maximize the recovery of nonrenewable resources from solid wastes.

Both the industry and, more recently, the Environmental Protection Agency have recognized the importance of this situation and its unresolved nature, and two recent EPA studies specifically address aluminum industry solid waste management. One study (3), identifies reduction cell linings, skimmings, and floor sweepings as potentially hazardous waste sources. Another study (2), highlights the reclamation and disposal of reduction cell lining residues as one of several unresolved encironmental problems before the industry.

In 1976, solid waste management came into sharper perspective with the passage of the Resource Conservation and Recovery Act (RCRA) (6), with broad industry backing. The law raises significant questions for the basic materials industries in the areas of recycling postconsumer waste and of disposing of hazardous process wastes. It has spurred interest within the aluminum industry in the concept of developing a single potlining recovery operation that might service several plants in one geographic region. Operated by possibly one or more independent entities, such facilities would reclaim chemicals and neutralize toxic components before ultimately disposing of innocuous residual materials.

The RCRA gives the States a fixed timetable to develop comprehensive solid waste management plans. The effect of the regulations will be eventually to prohibit outright dumping of hazardous wastes and, in all likelihood, to encourage the phasing out of certain practices currently associated with the onsite storage or disposal of spent potlinings.

At this point it may be appropriate to list some barriers that may be inhibiting a comprehensive solution to the problem. Although the list reflects in part the views previously expressed by various professionals in the industry, it is the opinion of the writer that clear recognition of obstacles other than those of a purely technical nature is an important first step in their resolution. The list follows:

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1. Scale economies for a complete recovery facility lie beyond waste volumes generated by a single plant. This factor has discouraged individual companies from undertaking the project unilaterally.

2. Certain companies or certain plants use unconventional bath additives (for example, lithium) at additional costs. There may be reluctance among these companies to pool wastes in such a way as to dilute the additive throughout the industry.

3. Concern over possible Federal antitrust action may have discouraged an organized effort by the aluminum industry to solve the problem jointly.

4. There are already well-established sources of virgin materials.

5. There is strong reluctance to adpot technology--and assume the royalty costs--developed by outsiders.

6. Basic differences exist bwtween plants operating wet versus dry air pollution control systems in demand for type of fluoride (cryolite or aluminum fluoride).

7. Corporate resources have been heretofore claimed by other priorities.

A survey of potlining recovery practices in the domestic primary aluminum industry (mid-1977) indicates that (1) approximately 800,000 tons of spent potlining exists at various plant locations and is being generated at annual rate of approximately 190,000 tons, (2) recovery technology at certain smelters is adequate for partial recovery of chemical values (cryolite or carbon) or energy, (3) available technology can be used to recover high percentages of carbon, fluoride, and alumina from the annual production by economic and environmentally acceptable means, and (4) future technology may permit the recovery of substantial percentages of these values from the inventory.

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POWERPLANT FLY ASH AS A SOURCE OF ALUMINA

by

M. J. Murtha[1] and G. Burnet[2]

Nearly all the alumina produced today comes from bauxite found largely in the developing countries. As a result of fiscal and political activities in these countries, bauxite reserves have become less secure to consuming nations (2). Some producing countries have nationalized mines, sharply increased royalties, assumed Government operation of new mines and plants, and promoted cartel-type joint price control.

The cost of bauxite has increased substantially because of action by the International Bauxite Association (IBA) and because of higher freight and labor charges. In the past five years, the tax levy on bauxite from Jamaica, Haiti, and Surinam has increased from $2 per ton to $20 per ton of bauxite ore. These countries, with Guyana, supply about 80 pct of the bauxite from the U.S. aluminum industry; 90 pct of the bauxite used in this country is imported.

The above factors have led to renewed interest in the development of processes for alumina production from raw materials other than bauxite. In some countries alumina is already obtained from other raw materials. In the U.S.S.R., for example, bauxite supplies are limited and alumina is extracted from nepheline, a waste product from the processing of nepheline syenite, to obtain apatite (3). It would appear to be sound policy for the United States to develop processes for production of alumina from alternate materials in order to insure future availability (1).

One such material is fly ash from powerplants that burn pulverized coal. Currently, over 40 million tons of fly ash, much of which contains significant amounts of alumina, are generated annually in the United States. A process has been developed in which fly ash is sintered with lime and soda to form soluble aluminates that can be extracted and recovered. The amounts of lime and soda used must be precisely controlled to obtain maximum recovery; the required amounts depend upon the ratio of alumina to silica in the fly ash. Under optimum conditions, over 90 pct of the alumina in fly ash can be recovered.

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A STUDY OF INDUSTRIAL WASTE MATERIALS EXCHANGES OPERATING IN EUROPE AND NORTH AMERICA

by

R. G. W. Laughlin[1] and H. Mooij[2]

The concept of the waste exchange is predicated on the old adage that "one man's meat is another man's poison," or as it might be restated today, "one man's garbage is another man's gold." Waste industrial materials may well prove to be a useful feedstock for another company.

In order that companies may consider using a waste material, they must first know of its existence. This is achieved by a Waste Materials Exchange, which may be defined as a vehicle by which the availability of waste materials or byproducts is made known to potential users. Other, less formal definitions suggested to us during the study were "industrial flea market" and "industrial bargain hunters' press."

Large companies with many processes and skilled chemical engineers are likely to find numerous recycling opportunities within their own manufacturing facilities. However, even engineers in large national companies are not likely to recognize all waste transfer opportunities outside their own industry. Thus, the concept of spreading the word about the availability of particular waste streams is attractive in that it increases the number of people examining possible uses for the waste.

The basic philosophy behind the operation of a waste materials exchange is to help return much of what is now regarded as waste to an alternative industrial use. This may be achieved directly by one industry "buying" waste as a substitute raw material, or it may occur via some intermediary such as a reprocessor or scrap dealer.

The objectives for such an exchange are--

1. To save valuable raw materials,
2. To save energy by not having to process raw materials, and
3. To avoid environmental damage--
    (a) In the winning of raw materials and energy, and
    (b) In the avoidance of having to dispose of the waste.

It would be very naive to imagine that a waste exchange will eliminate all problems of waste disposal. There are many waste materials for which no use is ever likely to be found. A recent study (1-2) of waste exchanges by Arthur D. Little for the U.S. Environmental Protection Agency concluded that, of a total industrial waste (generated by 14 major industrial sectors in the United States) of about 206 million metric tons per year, 3 pct has potential value--a total of 6 million metric tons. Using a 10:1 ratio for Canada, some 600,000 metric tons of waste might be considered potentially transferable.

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Wastes generally recognized as having components of potential value include those having high concentrations of recoverable metals, solvents, alkalis, concentrated acids, catalysts, oils, and combustibles. A. D. Little's report included the following estimates of percentages of waste potentially transferable from four industry groupings:

SIC No.	Industry	Transferable wastes, pct
2911	Petroleum refining..............	63
2865, 2869	Organic chemicals...............	22
2884	Pharmaceuticals.................	17
355	Small industrial machinery.......	17

In the analysis of likely waste transfers in the chemical industry, A. D. Little concluded that transfers of waste materials are more likely to take place--

1. From larger companies using continuous processes to smaller companies using batch processes,

2. From basic chemical manufacturers to formulators, and

3. From industries with extremely high purity requirements (for example, pharmaceuticals) to those with lower purity requirements (for example, paints).

The waste materials exchange will most probably be effective in encouraging transfers between different industries rather than internally within one industry where personnel are more aware of recycling opportunities.

Costs for the operation of the existing waste materials exchanges are not well defined. In the cases of industrial societies and chambers of commerce, the costs were absorbed within general budgets. The United Kingdom exchange was funded with a $100,000 grant for a 2-year period of operation. St. Louis and the French waste exchanges were the only two exchanges making a charge for the use of the service. St. Louis makes a $5 charge for each waste listed. The French exchange, operated by the magazine Nuisances et Environment, charges normal, classified advertising rates for listing. Only the United Kingdom exchange has made any attempt to evaluate the impact of its operations. They assessed the first 125 wastes that transferred on the basis of "the value of the raw materials which these wastes replaced." This totaled $8 million for these 125 items. It can be argued that this is not a particularly accurate analysis since no costs are assigned to transportation or any reprocessing of the wastes (if necessary). However, no credit is taken for not having to dispose of the waste materials. If one rationalizes that the disposal credit and reprocessing costs would on average balance out, this figure of $8 million does at least indicate the approximate value of the exchange's operation.

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BENEFICIATION OF STEEL PLANT WASTE OXIDES BY ROTARY KILN PROCESSES

by

H. Rausch[1] and H. Serbent[2]

Iron and steel making inevitably involves the generation of dusts which have to be taken off from the waste gases. Since the construction of the first filters for this purpose, metallurgists have been dealing with the question of the further use of these materials. The increased steel production, the improvements in filtration equipment, and thus the accumulation of greater quantities of finer dusts have continuously aggravated these problems. The recirculation of the zinc- and lead-containing materials, which are difficult to handle, as well as their dumping are not solutions that can be generally applied. In the blast furnace operation zinc causes difficulties which, particularly in the case of big furnaces, are of great economic importance. In the event of dumping, not only the nonferrous metals but also a considerable quantity of iron is lost. Since the quantity of galvanized scrap treated in the steel plants will continuously increase, the difficulties resulting from the raw materials will hardly diminish.

Processes suitable for the treatment of these waste oxides should fulfill the following prerequisites:

1. Treatment of individual materials and mixtures, the chemical compositions and physical properties of which may vary within a relatively wide range during a short time.

2. High metallization of the iron content of the raw materials and conversion into a lump-size product suitable as blast furnace feed.

3. Removal of zinc and lead down to contents allowing a recirculation of the treated material to the material flow of the iron and steel works.

4. Enrichment of the nonferrous metals in a flue dust that can be used by nonferrous smelters for recovery of these metals.

Some of these demands are met by rotary kiln processes which have been known for a long time. Thus, zinc and lead are separated from ores and intermediate products by reducing volatilization according to the Waelz process, which has been applied in the nonferrous metal industry for about 50 years. Similar reducing conditions prevail in rotary kiln processes for production of sponge iron by using solid reductants unsuitable for the blast furnace.

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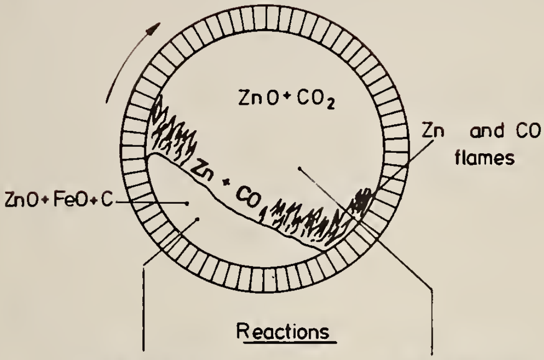

In the charge

1. $ZnO + CO \rightleftharpoons Zn + CO_2$
2. $CO_2 + C \rightleftharpoons 2CO$ } +

3. $ZnO + C \rightleftharpoons Zn + CO$

1. $FeO + CO \rightleftharpoons Fe + CO_2$
2. $CO_2 + C \rightleftharpoons 2CO$ } +

3. $FeO + C \rightleftharpoons Fe + CO$

In the freeboard

1. $Zn + \frac{1}{2}O_2 \rightarrow ZnO$
2. $CO + \frac{1}{2}O_2 \rightarrow CO_2$

FIGURE 1. - Zinc volatilization and reduction of iron oxides in the rotary kiln, schematically.

Consequently, it was necessary to examine available technologies with regard to their utilization for the solution of this problem and to modify accordingly, if necessary. For this purpose, research and development work was carried out, from laboratory investigations through industrial-scale trials.

Figure 1 shows the principle of the operating method taken into consideration. The kiln charge containing solid, carbonaceous reductant travels through the inclined kiln in countercurrent flow to the oxidizing kiln gases in the kiln freeboard. Zinc and oxide are reduced under the decisive influence of the Boudouard reaction. The zinc then emerging as metal vapor from the charge together with carbon monoxide is oxidized in the free kiln space and leaves it together with the waste gas in the form of a flue dust which can be separated from the latter. The CO emerging from the material surface causes the separation of the oxidizing from the reducing atmosphere prevailing above and within the charge.

The SL/RN process and the Waelz process represent extreme cases with regard to material preparation and the lump size of the dezincified material. Between these extreme cases can be classified the rotary kiln processes in which, for example, green pellets are dried before they are charged to the kiln. None of these processes can avoid the accumulation of certain quantities of fines. Thus, even in the version of the SL/RN process used by Nippon Kokan about 5 pct minus ¼-inch fines are obtained which are also briquetted there. As compared with the nonbriquetted coarse material, the briquets can be better stored and transported.

The process selection depends both on the iron content and on the zinc and lead content of the waste oxides. With iron contents of about 55 pct and relatively low contents of nonferrous metals, the SL/RN process including its material preparation is to be given preference. In the reverse case, which is usual, the Waelz process offers greater advantages. It affords a greater flexibility as compared to the variations occurring for these materials, uses a simpler rotary kiln without air admission tubes, and thus represents a relatively cheap zinc bleed-off for the iron industry.

"CANMET" WATER RECOVERY SYSTEM FOR INDUSTRIAL EFFLUENTS

by

H. A. Hamza[1] and N. E. Andersen[2]

With the current rapidly increasing usage of water for public supply and for industrial purposes, there have been corresponding increases in effluent volumes.

Industry uses vast quantities of water for processing, transport, steam generating, heat transfer, solvent extraction, and fire protection. Every plant does not necessarily use water in all these ways; instead, water usage varies widely among different types of industry. In the mining industry, for example, water may be used directly in mining as a dust suppressant, for hydraulic mining, and/or for ore beneficiation. Hydraulic mining consumes especially large volumes of water; for example, the Florida pebble phosphate industry uses about 7 tons of water for every ton of ore mined. Similar consumption has been reported for the hydraulic mining of a Canadian coal. Coal preparation requires up to 5 tons of water for each ton of coal processed. In froth flotation, a common operation in mineral processing, the weight of water being used may be as high as 7 times the weight of ore being treated. In a pulp mill, as much as 20 tons of water must be clarified to produce 1 ton of pulp. Gas processing plants and oil refineries consume vast quantities of water for steam production and cooling purposes.

Plant effluents usually contain a high level of dissolved solids, metal ions, residual process reagents, chemical complexes, etc., in addition to suspended solids, which generally exist in a colloidal state. In most cases these streams are discharged to tailings impoundments where the solids are retained and the supernatant is treated prior to discharge into water courses or recycle to the plant. Depending on the nature of the process, the water may become unsuitable after one or more recycles. Very often, however, the addition of makeup water will maintain soluble constituents at tolerable levels and thereby allows continuous circulation of water.

The degree to which the final discharge can be reduced by recycling is dependent on the process requirements, the treatability of the effluent, and ultimately, the efficiency of treatment. The degree of recycle practices by base metal mills in Canada, for example, has increased dramatically in recent years, and recycling now provides 60 pct or more of process requirements. Future increases in recycling of water will be brought about not only by increasing water costs but by environmental regulations. For example, the U.S. Environmental Protection Agency (EPA) Effluent Guidelines and Standards (1) promulgated May 13, 1976, demand, zero effluent discharge from coal

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preparation plants. This requires fully closed water circuits and prohibits discharge of process water from a wash plant, tailings pond, slurry pond, or other area of impoundment into the surrounding environment. All process water must be treated in such a way that its effectiveness as a washing medium is maintained. Because of the many types of contaminants accumulating in a coal processing medium, this requirement cannot always be fully satisfied. Land-use priorities have made large tailings ponds increasingly objectionable, and as such, the water clarification system will form a critical part of any coal beneficiation plant.

The Canmet water recovery system has been successfully applied to a variety of clay and coal washery tailings. Characteristics of some typical effluents are summarized in table 1. Using the previously described procedure for flocculant selection and evaluation, three superior flocculants for each effluent are indicated in table 2. The ranking order shown is based on the flocculant cost per unit of settling rate and may change if other factors are considered. Flocculant cost depends on the dosage required and the commercial price of the flocculant.

TABLE 1. - Effluent characteristics

Sample designation........	CR	CP	FP	HC
Sample description........	Coal froth flotation tailings	High-sulfur coal slimes	Pebble phosphate slimes	Thermal coal--fine tailings
Solids density.....g/cm^3..	2.09	1.79	2.70	2.30
Solids content....wt-pct..	0.6	4.0	2.6	4.3
Ash content.......wt-pct..	45.6	43.0	-	70.0
Zeta potential........mv..	-18	-20	-	-21
Ions in solution, ppm:				
Ca^{+2}....................	30	80	47	488
Mg^{+2}....................	9	28	13	205
Na......................	42	91	6	154
K.......................	-	9	-	33
SO_4^{-2}..................	-	700	54	2440
Cl^-....................	-	20	10	5
pH......................	8.2	6.9	7.6	7.2
Median particle size..µm..	18	25	1.2	12

In summation, it may be stated that most water-circuit closing problems can only be effectively dealt with through a thorough knowledge of the solid-liquid system at hand, together with pilot studies including jar tests and familiarization with the nature and technology of flocculants.

TABLE 2. - Ranking of selected flocculants

Sample	Flocculant ranking[1]	Flocculant	Manufacturer	Settling rate at optimum dosage, in/hr
CR	NAp	None...............	NAp................	7.1
	1	Separan MG700......	Dow................	625
	2	Superfloc 1202.....	Cyanamid...........	535
	3	Percol E24.........	Allied Colloids....	738
CP	NAp	None...............	NAp................	12.6
	1	Hercofloc 819.2....	Hercules...........	2,590
	2	Poly-floc 1100.....	Betz...............	2,590
	3	Separan MG700......	Dow................	2,340
FP	NAp	None...............	NAp................	.5
	1	Superfloc S3803....	Cyanamid...........	863
	2	Separan AP273......	Dow................	2,070
	3	Percol 352.........	Allied Colloids....	1,725
HC	NAp	None...............	NAp................	2.4
	1	Praestol 2935/75...	Stockhausen........	425
	2	Separan MG700......	Dow................	525
	3	Superfloc N100S....	Cyanamid...........	305

NAp Not applicable.
[1]Ranking based on flocculant cost per unit settling rate.

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SCRAP METAL

OVERVIEW

by

H. Cutler[1]

Although there have been significant technological changes affecting mineral waste utilization since the first Bureau of Mines-IITRI Symposium in 1968, we somehow find ourselves today faced with many of the problems that prompted that meeting.

Even a casual review of the proceedings of the five previous symposia provides a stark contrast and insight to the changes in technology and priorities in waste utilization that have occurred.

As a point of reference, the ferrous scrap market in 1968 was weak, with domestic purchased scrap receipts totaling 36.7 million net tons. The annual average composite price for No. 1 Heavy Melting Scrap that year was only $25.86 per ton, its lowest level since 1946; the No. 2 Bundle price was a mere $20.11. The open-hearth furnace was still king, but in 2 years it would lose that title to the basic oxygen furnace. The electric furnace was beginning a modest but steady gain that in 1975 resulted in its also overtaking the open hearth in steel output. Equaling a previous record, 131.5 million net tons of raw steel was poured in 1968: 50.1 pct by open hearths, 37.1 pct by BOF's, and 12.8 pct by electrics. Domestically, the United States mined 96.2 million tons of iron ore and imported 49.2 million net tons, or 34 pct of the total iron ore needs of this country.

At that first symposium, the Bureau's then Deputy Director, Earl T. Hayes, took the point of view "... that we have failed thus far in an essential mission, which is to convince the general public that mineral resources are not inexhaustible, that depletion is real and permanent in the case of many ores and that conservation of mineral byproducts is an urgent necessity..."

There was certainly mounting evidence in the Nation's dumps, landfills, countryside, vacant lots, and city streets that Mr. Hayes was in part correct. I say "in part" because the public crescendo was building that would lead to the first Earth Day in 1970. In this instance, I think it is fair to say that the people were pushing Government leaders to take action--the Government was not pulling the people.

The public mood that was forming at the time of the first symposium was in the process of erupting when the second was held, as characterized again by Mr. Hayes when he said, "important changes have taken place since the first symposium... At that time the issue of environmental quality had not assumed

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the grip it now holds on the public consciousness. President Nixon ... has designated the 1970's as a now or never decade in which we must move to restore the quality of our air, our water and our land ..." The President also said that the seventies "absolutely must be the years when America pays its debt to that past...," a debt, in the case of metallic scrap, we are still increasing.

President Nixon had made that statement 3 months earlier on January 1, 1970, when he signed into law the National Environmental Policy Act, which created the Council on Environmental Quality and required each Federal agency to prepare a statement of environmental impact in advance of each major action, recommendation, or report on legislation that might significantly affect the quality of the human environment.

Almost a month to the day following the second symposium, Earth Day was held. Although the Federal commitment was significant, the tempo of Earth Day indicated that much of the initiative for environmental action was still coming from the people.

It was at the second symposium that Hollis M. Dole, then Interior Department Assistant Secretary for Mineral Resources, pointed out that secondary materials and metals represented "our only growing resource," a phrase that would be quoted often.

During the summer of 1970, still on the crest of public momentum, the Council on Environmental Quality transmitted its first annual report to the Congress and stated that "maximum recycling and reuse of materials are necessary to reduce the growing volume of solid wastes that must be disposed of."

Two months later, the Congress passed and President Nixon signed into law the Resource Recovery Act of 1970--waste disposal of the sixties became resource recovery in the seventies. This act also created the National Commission on Materials Policy, which subsequently prepared a major report only to find that its recommendations were virtually ignored by its creators, the Congress.

By the end of 1970, through the executive reorganization plan, a new Government entity was created--the U.S. Environmental Protection Agency, and within that agency, the Office of Solid Waste Management Programs.

Thus in just one year, the Nation was exposed to the most far-reaching series of actions dealing with environment and solid waste in its history. It was a time of positive anticipation for those who were committed to the benefits and necessity of increased recycling.

Based on these events, Mr. Hayes may have been premature to admit failure in 1968. Public consciousness probably began to accelerate with the passage of the Highway Beautification Act of 1965, and there was considerable attention to the problem of abandoned and junked autos at that first symposium.

William A. Vogely, the Bureau's then Assistant Director for Mineral Resources Development, observed, "Other obsolete scrap cycles are quite

inefficient and may involve considerable spillover damages to society as a whole, as with junk autos..."

While the Bureau recognized the problem, it also realized that junk autos represented a resource not to be wasted, but to be recycled. And although there was some minor reference to the then relatively new technique of shredding, the focus of automobile scrap was the No. 2 Bundle--a drudge on the 1968 market at $20 a ton.

As an aside, going back now to 1970, there was at least one projection made at that meeting and it is always interesting to see how close forecasters come to reality. Granted projections are a risky exercise, but that risk is to the individual who chooses to indulge in calculations of the future. In this particular case it was projected that shipments of iron and steel castings, reporting at 17.6 million net tons in 1968, would double by 1980. Preliminary figures show that 1977 shipments were at 17.6 million net tons, and shipments over the past 10 years (1968-77) have averaged 17.6 million net tons. With 3 years to go, I'm sure the ferrous scrap and foundry industries are hoping that this 1970 prediction will come true.

At that meeting, Bureau researchers reported on their investigations of foundry iron production from automobile scrap, pollution-controlled incineration of automobile hulks, and the recovery of nonferrous metals from shredder residues. It is also interesting to note the concern expressed with high freight rates for ferrous scrap and the shortage of gondola freight cars in which to ship scrap--two problems that are definitely yet with us.

The relatively new agency, EPA, was also represented at the 1972 symposium. The then Assistant Administrator of Categorical Programs, David C. Dominich, stated, "... We are concerned with the economics of resource recovery, with the present legal discrimination on secondary materials imposed by freight rates, and with other market factors that have inhibited a greater degree of resource recovery in the past. We understand that the problems of greater material recovery cannot be solved solely by technological advances--the market for reclaimed resources must also be responsive."

Attention has shifted to the municipal solid waste stream, and the fact that we have more of it than we knew what to do with, but we also knew that we had to do something about it.

Fred Berman, then president of the Institute of Scrap Iron and Steel, summed up the scrap industry's feeling, which still holds, when he said, "Certainly our objective is recycling, but our attention must be directed first to the need for more demand, not more supply."

Two researchers from Battelle Columbus Laboratories who presented a paper offered the caution, "Recycling is so obviously appealing that many people are instantly taken with the idea. They see it as a simple and obvious way to solve problems of resource depletion and waste disposal. Although it is true that recycling is a potential solution, it is not simple or obvious. There are many obstacles to the effective implementation of the recycling concept on a scale larger than the present one."

The junk automobile was still a concern in the spring of 1972. The fact that 1971 had been a relatively poor year for total scrap demand clearly influenced the problem, and two Bureau researchers concluded that "regardless of the solutions to abandonment which are eventually chosen, and there may be as many as there are local governments, it appears that government programs must be part of the solution. While changes in technology and market values will certainly help the movement towards a solution, it simply does not appear that the marketplace, by itself, will solve the auto abandonment problem."

To the contrary, the strong demand for ferrous scrap in 1973 and 1974 indicated that the marketplace could solve the problem, if there was a sustained demand for the product.

The impact of municipal refuse in this country was demonstrated at the fourth symposium by the number of presentations dealing with solid waste. While there had been some mention of converting this "resource" to a fuel in 1972, it was obvious in 1973 that the United States had experienced an energy shock and thus more interest was engendered.

Further reports were presented by Bureau personnel on research dealing with auto and ferrous refuse scrap in cupola iron production and the separation of nonferrous metal concentrates from auto shredder nonmagnetive residues. The use of cryogenics as a processing technique was also discussed.

Like the previous seminar, 1976 again placed heavy emphasis on municipal solid waste and included many papers on resource recovery and energy systems throughout the United States and in other countries.

Of particular interest to the session on scrap metals was the presentation by an A. T. Kearney, Inc., associate entitled, "Scrap Demand Versus Newly Available Supply 1975 - 1985." This paper concluded "It appears that the domestic scrap supply can support the forecasted levels of mill and foundry operations and the resulting derived demands. Recall that the total demand for scrap did not include export demand, which for the three years 1972-74 averaged nine million tons, excluding shipwrecking operations. From a preliminary net balance results, this level of export activity cannot be supported from the supply of newly available ferrous scrap if the demands for domestic consumption are to be met."

It was further estimated by that paper that 1976 domestic raw steel production would reach 141 million net tons, resulting in steel shipments of 128 million net tons. However, when the year was over, the final figures revealed that only 98.5 million tons of steel were poured and 89.4 million tons of steel was shipped. The projection was off by some 30 pct.

There is little doubt that the record domestic demand for ferrous scrap in 1974 prompted this and numerous other studies dealing with the "future availability" of iron and steel scrap. Although the marketplace went into a downward spiral following that record year, the forecasts of scrap shortages continued even though domestic demand dropped by 28 pct, or nearly 15 million tons.

To conclude this overview, I would like to cite the remarks of Murray A. Schwartz in the foreword to the proceedings of the first symposium. He stated that "technological solutions" to the problems of waste disposal are the "objectives of this symposium." He expressed the hope that the meeting "will act as a turning point in our national thinking towards a positive approach to a number of problems including scrap accumulations and natural resource depletions."

While I would not deny the importance of technological innovation and the progress that has been reported at the five previous symposiums, what is needed is an equally innovative approach to the economics of the marketplace. This point, as I noted earlier, was made by EPA's David Dominich. The marketplace discrimination he described continues to plague us and becomes ever more apparent as our ability to separate metallic waste becomes more sophisticated.

The marketplace is affected by economics; the roots of those economic problems can be found in the law; and the law is the domain of politics.

To paraphrase Earl Hayes, we have failed to convince this Nation's Government leaders that mineral resources are not inexhaustible, that depletion is real in the case of many ores, and that conservation of mineral byproducts is an urgent necessity. If it was an urgent necessity in 1968, and I share Mr. Hayes' belief that it was, the urgency should be unmistakable today.

THE BACKLOG OF IRON AND STEEL DISCARDS IN THE UNITED STATES

by

H. Cutler[1]

The ferrous scrap marketplace is a classic textbook example of the economist's supply and demand factor at work. A freely traded commodity, scrap is subject to sharp peaks and valleys and is characterized by a large number of highly competitive suppliers and a relatively small number of buyers.

The erratic nature of the scrap market is caused in part by the way in which the commodity is purchased, generally on 30-day contracts. Conversely, the other major raw material inputs to the iron and steel making processes are generally either owned or controlled by the ultimate consumer, or long-term contracts are utilized, providing a sense of stability.

A third characteristic of the industry centers around how obsolete scrap gets to the processing plant. Through an informal system of collectors and peddlers, who have as their motivation the price paid for the "old iron" at the processor's scale, discarded scrap moves to the scrap plant. In some cases, 90 pct of a processor's intake of materials may come from peddlers. One processor reports dealing with up to 100 different peddlers daily.

The collection system functions at its best when there is a sustained strong demand for scrap and at its worst when the market for scrap is depressed. However, unlike other raw materials, there is no way to stop the generation of metallic discards. They are not intentionally produced. Scrap happens, throughout the country, where there are people. While you can stop the production of iron ore, coal, or limestone by closing the mine, scrap keeps coming. Rather than closing, the mines aboveground grow larger and larger as society's discards pile up.

With rare exceptions, the late fifties through the sixties and into the seventies were not outstanding years for the scrap-processing industry. During the 15-year span from 1958 through 1972, the average of the annual average composite price for No. 1 Heavy Melting Steel Scrap was $33.23 per ton. Domestic purchased scrap receipts averaged only 31.7 million net tons and exports averaged 7 million net tons during the 15-year span.

This was to change, however, in 1973 with a worldwide increase in the demand for steel and subsequently in the need for scrap. New records for both domestic and export purchases of scrap were established that year, 44.7 million net tons and 11.3 net tons, respectively.

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The domestic record was to stand for only 1 year, since purchases increased an unprecedented 15 pct to 51.3 million net tons in 1974. As a result of export restrictions imposed in mid-1973, exports of ferrous scrap in 1974 dropped to 8.7 million net tons. (Those restrictions were lifted on December 31, 1974.)

In 1973 and 1974 scrap iron began flowing at a rate never experienced in this country. As a result, many scrap consumers alleged that the scrap-processing industry lacked the capacity to process the scrap required and that there was not sufficient scrap available to meet both the domestic and the export demand.

Unlike other recent studies dealing with scrap iron availability, this study makes no predictions about the future behavior of the scrap inventory. It is apparent, nevertheless, that the size of the scrap reservoir in the future will depend on a number of interrelated factors, paramount among which will be technological developments and practices in the iron and steel making industries (domestically and internationally); rates of technological, economic, or physical obsolescence of ferrous metal products; and the long-term relationship between the total cost of producing steel from iron ore as opposed to ferrous scrap.

No forecast is required, however, to identify a pool of obsolete ferrous scrap available as of December 31, 1975 (636.2 million net tons as shown in table 1), which is sufficient in size to satisfy fully the total purchased scrap requirements, at the 1977 level, of the entire U.S. steel and foundry industries, plus the export demand, for nearly 14 years, or until 1992. And this does not consider the millions of tons of new obsolete scrap generated each year and not recycled.

TABLE 1. - Total inventory (adjusted for corrosion loss) by region

(Thousand short tons)

Census region	1955 inventory (1)	1956 additions to inventory (2)	Total inventory through 1975 (1) + (2)
New England	40,800	28,611	69,411
Middle Atlantic	24,705	17,293	41,998
East North Central	58,393	40,940	99,333
West North Central	71,494	50,080	121,574
South Atlantic	59,891	42,023	101,914
East South Central	6,363	4,403	10,766
West South Central	62,511	43,644	106,155
Mountain	23,208	16,125	39,333
Pacific	26,951	18,782	45,733
Total	374,316	261,901	636,217

Obviously, most previous forecasts of future scrap shortages have not scientifically calculated the tremendous reservoir of obsolete iron and steel scrap which has accumulated through the years.

While the fact that we have a 636-million-ton backlog of ferrous scrap for recycling could be seen as a national asset, it is, in reality, a national tragedy. The fact that an additional 100 million tons of recyclable scrap iron has been allowed to rust away is a national disgrace. Had that 100 million tons been recycled, the energy savings alone in making new steel from this material would be equivalent to 14 billion gallons of gasoline. The 636-million-ton reservoir, if used instead of iron ore to make new steel, represents an energy saving equivalent to more than 89 billion gallons of gasoline.

It is obvious that this country must come to grips with the public policy questions that have led this Nation to virtually ignore its manmade resources while depleting irreplaceable virgin resources whether they be mined here or imported from around the world. Public policy makes it more economically attractive to mine and transport raw material from all over the world than to use readily available domestic ferrous scrap from within American borders.

Actions should be directed toward increasing the use of iron and steel scrap in order to avoid this continual buildup of our naturally acquired and internally generated scrap resources, and their eventual loss to the system because of disuse. The energy savings alone make this step mandatory for the good of the American people.

In terms of energy and mineral savings, and the improvement in environmental quality, there is much to be gained when there is a greater use of ferrous scrap in the making of new iron and steel products. The challenge before us is to take this backlog of discarded metallics from a social liability to its rightful and proper place as a national economic asset.

BARRIERS TO THE USE OF SECONDARY METALS

by

B. M. Sattin[1]

The recycling of scrap materials has become a much-discussed topic in recent years. Many benefits from recycling have been identified, including decreased dependence on finite natural resources, reduction of solid wastes that would otherwise require land-intensive disposal, energy savings, reduction of environmental problems caused by mineral extraction and processing, and many others.

The fact that these benefits have not been fully realized is also the subject of considerable discussion, which often focuses on various Government-imposed obstacles, or barriers, to recycling. Several of these so-called barriers were identified by previous studies or brought to the attention of Congress and Federal regulatory agencies by the trade associations representing the scrap-processing industry. No study, however, has previously attempted a systematic search for these barriers or has developed cost estimates of the impact of more than two of the barriers already identified.

This article is a condensation of a report (1) resulting from a 2-year study effort funded by the Bureau of Mines to identify barriers created by government at the Federal, State, and local levels to the reuse of secondary metals. Once these barriers were identified, basic information concerning them was developed so as to permit the formulation of legislation to lessen the impact of those barriers found to have a significant effect on the recycling of scrap metals. Forty-one potential barriers were identified and ranked, and the five most important were analyzed in detail.

Since most of the barriers identified had been originally intended to serve some useful and valid purpose, their current negative impact on the scrap recycling industry is an unintended result. The simple fact that a barrier has a detrimental impact on recycling is not reason enough, standing alone, to remove that barrier.

Although it is not suggested that all the identified barriers be repealed or amended, certain of them could be freshly evaluated in order to determine the following:

1. Is the law or regulation still necessary?

2. Is the purpose for which it had been intended being served?

3. Is the purpose served sufficiently important and is the intended effect sufficiently large to override the negative effect on recycling?

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[1]Research associate, JACA Corp., Fort Washington, Pa.

4. Even if the answers to the three questions above support the law or regulation, are some other means of accomplishing the intended purpose available that will not have as great a negative impact on the recycling industries?

Five high-priority barriers were studied in depth, and costs per ton of raw steel or secondary aluminum were calculated. Freight rate differentials were found to create a \$0.72/ton barrier to the use of scrap iron and steel and a \$3.31/ton barrier to the use of scrap aluminum. The percentage depletion allowance created barriers ranging from \$1.05/ton to \$3.21/ton to the use of scrap iron and steel and from \$3.06/ton to \$5.74/ton to the use of scrap aluminum. Automobile titling laws created barriers in the six States surveyed ranging from \$0.15/ton to \$1.22/ton against the use of scrap iron and steel. Procurement policies and pollution control requirements were <u>not</u> found to create barriers to the use of secondary metals. Subsidies to the secondary metals industries were found to result in only negligible increases in scrap utilization in the short term, but long-term increases in scrap aluminum consumption could occur.

The in-depth analysis of five high-priority barriers demonstrates that legislative actions have disadvantaged the secondary metals industries in relation to the virgin metals industries. Such factors as the extent and type of assets held by firms within the virgin metals industries permit utilization of some Federal subsidies which, while theoretically available to the secondary industries, are seldom actually applied because of size and extent of assets. Additionally, certain Federal subsidies are available only to the virgin metals industries because these subsidies have been designed to benefit only these industries. It may be concluded that, to the extent that subsidization is greater in the virgin metals industries than in the secondary metals industries, investors will favor the virgin metals industries. Potential for the expansion of firms within the secondary materials industries is thereby limited.

Paucity of data and lack of specificity and disaggregation of data make it impossible to measure the effects of any tax subsidy other than the percentage depletion allowance. However, the study did show that any subsidization of the secondary metals industries would result in negligible increases in scrap consumption. Similarly, elimination of the percentage depletion allowance would, in the short run, produce little change in scrap consumption.

The study also showed that subsidization of the secondary aluminum industry may, in the long run, produce positive effects on scrap utilization. Technological developments in the steel industry tend to make demand more responsive to price changes. Reduction or elimination of the depletion allowance under these conditions may have a greater long-run effect on scrap usage. It is concluded that more data would have to be made public by the primary metals industries to construct a cost-benefit analysis of the long-run effects of subsidization and elimination of subsidization in these industries.

Since auto salvage is performed for the used parts as well as the ferrous content of the vehicle, removal of unnecessary costs associated with automobile titling laws, such as reducing or eliminating the titling costs and

impoundment periods for cars of no value (as is done in Ohio) and eliminating notarizing costs, may have a small positive effect in moving more abandoned cars to auto salvagers for their used parts content without incurring any cost to the State. Effectiveness of proposed legislation would have to be determined by the results of an analysis of what cost and level of effort is necessary to strike an appropriate balance between protection of private property rights and the rights of society to an aesthetic environment.

Transportation rates and possibly services have been shown to favor the movement of virgin inputs into raw steel and primary aluminum and disfavor the movement of scrap iron and steel and aluminum. While the economic impact of these disparities is small in comparison to the prices of the commodities involved, they are perceived as significant barriers by scrap shippers. Consequently, more scrap is moving from processor to consumer by truck and less by railroad. Besides limiting the shipping radius of prepared scrap, this trend may have repercussions for the railroads that profit from scrap carriage.

Procurement policies and pollution control requirements were not found to mitigate against the use of secondary metals.

Economic analysis of barrier removal or subsidization of scrap utilization were found not to increase scrap use significantly in the short run, but longer term effects were noted as possible for scrap aluminum.

Based on the conclusions and observations recorded in the study, the following recommendations were made:

1. No form of direct subsidy should be given to the producers of steel scrap. However, it is recommended that a cost-benefit analysis of the long-run effects of subsidization of the secondary aluminum industry be undertaken.

2. The question of removing subsidies to the steel industry should be addressed, with full analysis of any side effects, taking into account that in the future a significant portion of steel production will be generated by relatively new technology.

3. As detailed information on the assets of primary and secondary metals firms in the aluminum and steel industries becomes a matter of public record, comparative studies should be undertaken to measure the total effect of all forms of tax subsidization in each industry.

4. Unnecessary costs associated with automobile titling laws should be removed by each State. This process may be facilitated by the development of model legislation that may be adopted by each State.

5. Alleged disparities in railroad transportation services to the virgin metals producers and the scrap handlers should be investigated by the Interstate Commerce Commission (ICC).

6. The ICC should establish criteria for evaluating point-to-point rates for hauling scrap metals and virgin inputs into primary metals by rail. These criteria should be applied when assessing new rate applications or protests against existing rates. All rates falling below a certain revenue-variable cost ratio should be ordered raised (with 1.00 as an absolute minimum ratio), and all those above a certain ratio (perhaps 2.00) should be ordered reduced.

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OPTIONS FOR THE COLLECTION AND RECOVERY OF HOUSEHOLD APPLIANCE MATERIALS

by

E. A. Kinne[1]

A great deal of publicity has been given to processing municipal wastes, recycling beverage containers, and recovering automobile resources. Yet there has been little consideration given to recycling appliances. Obsolete appliances represent a large and potentially valuable resource. In the next 10 years, 2 to 2.6 million tons of ferrous metals alone could be recovered annually from recycled appliances (2).

In 1972, a document prepared by the Institute of Scrap Iron and Steel (ISIS) (1) stated that there were 350 million major appliances in use in the United States, and that they were being discarded at the rate of 21 million units annually in 1971. The annual rate was expected to rise to 29 million units by 1980.

This document also stated that very few appliances were being recycled. The reasons given were--

1. The variety of materials contained in major appliances that require extensive processing to obtain quality scrap for steelmaking.

2. The values of units as scrap were relatively small.

3. The high cost of handling and transportation relative to the scrap value.

4. The lack of a centrally located continuous source of supply for a processor.

In addition to these limitations, some scrap specifications include a provision specifically prohibiting the inclusion of appliances.

The situation as outlined in the 1972 ISIS study still persists in many locations despite significant changes in technology, markets, legislation, and public attitudes. The service life expectancies of appliances are shown in table 1.

There are many ways to approach handling of appliances for recovery. The value to the original owner has declined to near zero when it is ready for discard. Interest in the product has changed from one of utility to one of disposal. Usually this means the easiest disposal, not necessarily the most cost effective approach.

[1]Consumer industry marketing representative, United States Steel Corp., Pittsburgh, Pa.

TABLE 1. - Service-life expectancy under one owner of selected appliances acquired new and acquired used[1]

Item	Service life July 1972, years	Standard error July 1972, years
Range:[2]		
Electric:		
New	12.1	1.4
Used	5.6	.7
Gas:		
New	13.5	1.4
Used	6.6	.7
Refrigerator:		
New	15.2	.9
Used	7.4	.6
Freezer:		
New	20.4	4.0
Used	9.3	1.9
Dishwasher:[3]		
New	11.1	1.4
Used	6.8	1.4
Clothes dryer:		
Electric:		
New	13.7	1.3
Used	5.1	.8
Gas: New	12.8	1.8
Washing machine (automatic):		
New	10.8	.5
Used	4.5	1.8
Television:		
Black and white:		
New	10.7	.5
Used	5.4	.4
Color: New	12.0	1.4

[1]New and used are not additive.
[2]Free-standing only.
[3]Includes both built-in and portable.

Source: Home Economics Research J., v. 3, No. 3, March 1975.

Because the ferrous fraction is such a significant factor in appliances, it could be useful to review the disposal of other consumer products fabricated from steel. I would like to suggest a three-category approach for analysis of steel consumer products destined for disposal.

1. Containers.--Hand-carried products including food and beverage containers and other items which fit into a garbage bag.

2. Appliances.--Deliverable products which may be moved manually, including discarded storage cabinets, files, furniture, and tools.

3. Automobiles.--Heavy products which require a machine assist to move, including home construction materials.

Just as each category of product reaches the consumer in a different manner, the path for return differs. Quantities must be accumulated along each step of return so that it is possible to optimize utilization of productivity of people and equipment.

The key is to accumulate full truckloads in the most efficient manner possible. This is essential in order that the truck driver can perform in a manner that will result in a profitable full-time hauling job. These systems are suggested for the above categories:

1. Containers may be hand-carried to a collection center, but the "easiest" system is to hire a collector, municipal or private. To justify trucking, all trash and garbage are collected at one time with separation at an accumulation point.

2. Appliances could be "dis-delivered" following the reverse route of delivering. The consumer may hire this collection through municipal or private pickup, or he may deliver the products himself to a collection center. Appliance dealers may also collect used units as a public service, utilizing their delivery system in reverse. A compactor is almost essential at the warehouse or collection center so that approximately 200 appliances at 200 pounds each may be loaded to a truck for transport to the processing plant.

3. Automobiles may be driven to a car collector, although some require a crane truck to take them to a center where full truckloads are accumulated. A crusher is probably needed to load a truck with 12 to 14 automobiles, weighing 3,000 pounds each.

The similarities between systems for handling automobiles and appliances are greater than those between containers and appliances. This suggests that the most effective system for handling appliances will more likely parallel that established for autos than that for municipal solid waste.

The supply of obsolete major household appliances exists on a continuing basis in most areas of the United States. Facilities to process appliance scrap into a high-quality resource are established in most highly populated areas. Markets for appliance scrap do exist in most areas. Legislation and regulation are pushing in the direction of resource recovery. The only unfulfilled requirements that remain are innovative handling systems to effectively move the appliance resource back into the existing processing stream.

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SEPARATION OF NONFERROUS METALS IN AUTOMOBILE SCRAP BY MEANS OF PERMANENT MAGNETS

by

E. Schloemann[1]

Starting in 1974 the Raytheon Research Division has developed and demonstrated simple, economical processes of separating nonmagnetic metals from waste material by means of permanent magnets (3-5, 7). The work was initially exclusively aimed at recovering the nonmagnetic metals from shredded municipal waste. More recently we have explored the application of the new separation methods to the processing of automobile scrap. The present paper describes the results of this study.

The primary economic incentive for the recycling of junk cars is the recovery of iron and steel, which make up approximately 80 pct of their weight. The value of the steel scrap depends strongly on its purity since the presence of other metals such as copper, zinc, and aluminum tends to degrade the quality of the steel obtained from the scrap. It is therefore highly desirable to separate the different metals as well as possible prior to remelting.

The desire to reclaim uncontaminated steel scrap from junk cars has sparked the construction of automobile shredders throughout the world. These machines are capable of digesting entire automobiles from which usually only the tires, fuel tanks, batteries, and radiators have been removed. The output of the automobile shredder consists of a mixture of particles, the largest of which are usually about fist size. Light materials, such as fabric, fibers, and light plastic, are removed from the mixture by blowing air through the shredder and collecting the light materials in an air cyclone. The steel is then removed by conventional magnetic separation.

The nominally nonmagnetic material which remains after magnetic separation, the "nonmagnetic shredder outfall," consists of about 33 pct of various metals, the remainder being glass, plastic, rubber, rocks, and dirt (2). The metals contained in the nonmagnetic shredder outfall are primarily zinc and aluminum, with smaller amounts of copper, stainless steel, and iron which escaped magnetic separation. Prior to 1970 this material was usually disposed of as landfill after a simple handsorting operation to remove the larger pieces of nonferrous metal. It has been estimated that only about 28 pct of the zinc and aluminum and 14 pct of the copper present in this fraction were recovered by handsorting procedures (1).

Since 1970 a growing fraction of the nonmagnetic shredder outfall has been shipped to central processing plants for extraction of the usable materials. Only very few of these plants are currently in operation. In these

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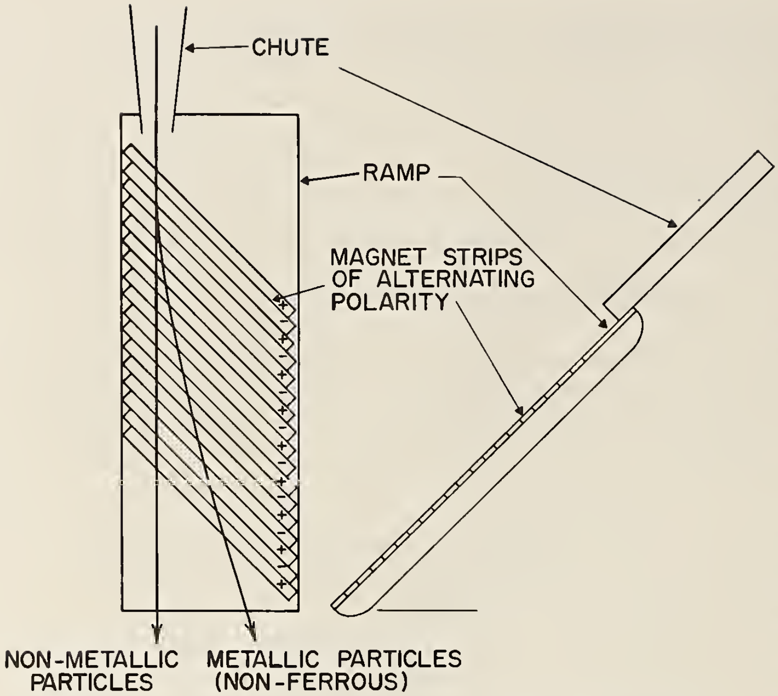

FIGURE 1. - Schematic diagram of the metal separator in frontal view (left) and side view (right). The shredded trash reaches the separator ramp through a chute. Nonmetallic particles continue to slide down. Metals are deflected in the manner shown in the diagram.

plants, the nonmagnetic shredder outfall is usually subjected to two stages of heavy-media separation: one to remove the metals as a group from the lighter materials, such as plastic and rubber; and a second to separate aluminum from the heavier metals such as zinc and copper. The copper is then removed by handsorting.

Figure 1 is a schematic diagram of one of the separators used in the present work. The operation of this sorter is very straightforward. The material to be separated travels over an inclined ramp, 8 feet long and 3 feet wide. Permanent magnets, which are made of inexpensive barium ferrite, are embedded into the ramp surface. The magnets lie in alternating strips of negative and positive polarity, each strip being oriented at a 45° angle to the trash flow.

As the waste material slides down the ramp through the magnetic field, electric eddy currents are generated in the metals. The interaction of these electric currents with the magnetic field forces the metals sideways, out of the waste stream (3). Nonconductive particles in the feed material--wood, plastic, cardboard, and glass--are not affected by the magnetic field, and they slide straight down. Thus, the metals and the nonconductive materials can be collected in separate bins at the foot of the ramp.

The simple separator described in figure 1 has the weakness that the separation process is seriously interrupted if the particles in the stream are strongly attracted by the magnets in the ramp and therefore become attached to the ramp surface, thus blocking the path for other particles. Even though most of the magnetic particles have been removed from the waste material before it reaches the nonferrous metal separator, enough remain to create a serious problem unless they are continuously removed. We have, therefore, constructed two metal separators which overcome the problem caused by residual magnetic particles in the feed stream: (1) The "self-cleaning" ramp metal separator (6), and (2) the rotary-drum metal separator (5).

On the basis of test results it is warranted to draw the following conclusions:

1. Both the ramp-type and the rotary-drum nonferrous metal separator can serve useful functions in the processing of automobile scrap.

2. Although partial segregation of aluminum and zinc can be achieved by eddy current separators, positive segregation has not been achieved and does not appear possible. Thus the eddy current separation techniques will not replace the heavy-media technique.

3. Eddy current separators installed at the site of automobile shredders can beneficiate the nonferrous outfall by removing rubber, plastics, fabric, rocks and dirt. Thus only a concentrated nonferrous metal fraction needs to be transported to a central processing plant (heavy-media separator) at considerable savings in transportation cost.

4. Eddy current separators used after heavy-media separation will improve the grade of the aluminum and zinc concentrates. Rocks and glass are removed from the aluminum concentrate (light fraction of heavy-media plant) and lead and stainless steel from the zinc concentrate (heavy fraction of heavy-media plant).

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CHARACTERIZATION OF SCRAP ELECTRONIC EQUIPMENT FOR RESOURCE RECOVERY

by

B. W. Dunning, Jr.[1]

Seven million pounds of obsolete military electronic hardware must be disposed of each year by the Defense Property Disposal Service (DPDS) of the Department of Defense. For example, 12.2 million pounds of electronic units were sold in fiscal year 1976 (1). Although processing technology is currently available, there is no integral system for dry-separating the conglomerate metals of electronic units into salable fractions. Therefore, DPDS has been marketing its electronic scrap together with scrap of lesser value, classified as irony aluminum. This scrap is sold for 6 to 10 cents per pound, although its true value may be considerably higher.

To better estimate the value of such electronic scrap, the Bureau of Mines, as part of its secondary resource recovery activity and under a cooperative agreement with DPDS, is assembling a continuous process experimental unit (PEU) that involves a series of dry-separation techniques. The process includes shredding, followed by wire picking, air classification, screening, magnetic, electrostatic, and eddy current separation methods. Additional treatments may be added to upgrade some of the metal fractions. The ultimate goal of this PEU is to obtain clean fractions of magnetic metals, aluminum alloys, copper alloys, nonmagnetic austenitic stainless steel, and nonmetals from shredded electronic scrap in order to assess its marketable value.

In a characterization study conducted for DPDS of a sample lot containing 36 separate electronic components available for scrap recovery, using current scrap values for base and precious metals, an estimated average value of $0.22 per pound was calculated. It was apparent that the 36-unit sample described in this study consisted of pre-1957 electronic black boxes and was not representative of higher value scrap that would be obtained from more recent electronic equipment.

Because of the variability in composition of electronic scrap, DPDS needs an efficient and reliable method of assessing its value. Current Bureau of Mines research involves the construction of a continuous PEU which will demonstrate the feasibility of mechanically separating electronic scrap into marketable fractions. When completed, this PEU will provide a direct and rapid means of accurately assessing the value of such electronic scrap.

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[1]Metallurgist, Avondale Metallurgy Research Center, Bureau of Mines, Avondale, Md.

PROGRESS IN RESOURCE RECOVERY IN APPLIANCE MANUFACTURING

by

T. H. Goodgame[1] and E. W. Hartung[2]

Industrial solid waste management has been discussed a great deal, usually from the basis of what further can be done to recover useful materials and energy and to decrease the quantities for which final disposal as waste is required.

One substantial study which has been done is that of Sobas, Vachon, and Goodgame (1), presented at the Detroit (1973) meeting of AIChE. At this time, it was shown that about 90 pct of the potential solid waste generated by the facility under study was already being recovered for reuse in the plant, or was being segregated and sold for recycle through the secondary materials industry.

Sobas' work indicated that the problem was essentially economic, and that the further reduction would only be achieved by changes in economic effects of taxes, regulations, energy cost, etc.

Table 1 shows the results that Sobas reported. Since that time, additional improvements in resource reduction and recovery have been made, ash shown in table 2. Recovery of potential solid wastes generated has been increased from about 87 pct in 1973 to 93 pct in 1977, equivalent to a reduction of 46 pct in solid wastes not recovered in 4 years.

What changes in operation would make recycling more profitable to the operator? Probably the largest single item would have been the ability, and willingness, to store the more valuable metals (copper, zinc, aluminum) until sufficient quantities were in inventory to obtain a good price from the scrap dealer. The same thing applies to motors, wires, coils, and stainless steel. Income from these items would have been increased 50 pct to 100 pct by this simple procedure.

Table 3 presents the income increase that would have resulted to the operator of a project if the sales price of the recovered materials had been the same as Whirlpool's St. Paul division was receiving for its scrap metal at that time. The increased income for the 22-month period is $5,456, or approximately $250 per month. This, added to the original net income, would make a monthly income of about $475. This is equivalent to a weekly salary of $220 for 40 hours per week, or an hourly rate of $5.50 per hour. This is certainly a comparable wage for many industrial jobs at that time.

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[2]Facility engineer, Whirlpool Corp., St. Paul Div., St. Paul, Minn.

TABLE 1. - Solid waste--1973 data, pounds per day

Item	Potential	Actual
Steel	87,020	Small (inc. in floor sweepings)
Plastics	1,920	10
Corrugated paper, etc	12,000	300
Containers:		
Pallets (nonreturnable)	3,990	50
Drums (nonreturnable)	209	133
Lube and hydraulic oils, drawing compounds	1,200	1,200
Paints, thinners, phosphate scale	1,056	1,056
Processing solids:		
Wastewater treatment plant	9,600	9,600
Strip salts and paint	1,320	1,320
Floor sweepings, cafeteria and office wastes	2,400	2,400
Scrap purchased parts	100	100
Total	120,815	[1]16,169

[1]13.4 pct solid waste not recovered.

TABLE 2. - Solid waste--1977 data, pounds per day

Item	Potential	Actual
Steel	87,020	Small (inc. in floor sweepings)
Plastics	1,920	10
Corrugated paper, etc	12,000	300
Containers:		
Pallets (nonreturnable)	3,990	50
Drums (nonreturnable)	209	133
Lube and hydraulic oils, drawing compounds	1,200	400
Paints, thinners, phosphate scale	1,056	1,056
Processing solids:		
Wastewater treatment plant	9,600	3,000
Strip salts and paint	1,320	1,320
Floor sweepings, cafeteria and office waste	2,400	2,400
Scrap purchased parts	100	100
Total	120,815	[1]8,679

[1]7.2 pct solid waste not recovered.

While it was not taken into consideration in the development of this data, there would also have been decreased expenses involved in less frequent trips to the scrap dealer.

Income could also have been increased by putting somewhat more effort into the disposal of collected fasteners to small repair shops, garages, and home handymen. This is not a large item, but could have provided a very good return for the effort involved.

TABLE 3. - Metals produced, pounds

	Price differential by volume disposal, cents per lb	Quantity, pounds	Increased income
Coated steel	1	358,860	$3,588.60
Uncoated steel	2	31,540	315.40
Cast iron	1	18,620	186.20
Stainless steel	7	1,251	87.57
Copper	11	1,484	163.24
Brass	20	1,552	310.40
Unburnt wire	No change	-	-
Coils, copper, and aluminum	No change	-	-
Aluminum	10	6,509	650.90
Zinc die cast	2½	3,694	92.35
Motors	1	5,106	51.06
Total	-	-	$5,445.72

Finally, what can the appliance industry do? The most obvious thing is to make appliances easier to take apart. Motors are a problem--could these be put in the units so that a blow from a sledge hammer, or simply loosening two bolts, would permit their easy removal? Could wiring harnesses be made easier to remove? Could motors be built so that the aluminum or copper in the winding could be removed more easily? There has been thought and effort in this direction, but progress has been slow because of the increased costs to the consumer. Consideration could also be given to reducing the number of different materials that go into any appliance. For example, if the motor is aluminum could the wiring and coil also be aluminum, and thus use no copper at all?

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RECOVERY OF CADMIUM FROM NICKEL-CADMIUM SCRAP BATTERIES

by

D. A. Wilson[1]

The manufacture and use of nickel-cadmium alkaline batteries began to grow in the late 1950's. During the period from 1966 to 1971, approximately 3 pct of the U.S. primary cadmium demand was consumed by battery manufacturers (4). From 1971 to 1975, the demand grew from 3 pct to 13 pct. It was estimated by the battery manufacturers (1) that by 1981 2.2 million pounds, or greater than 20 pct of the yearly U.S. demand for cadmium, will be consumed by battery manufacturers. The United States is dependent on Canada, Mexico, and Australia for greater than 60 pct of its primary cadmium supply.

At present, there is no commercial process being used in the United States to recover the total metal values from Ni-Cd battery scrap. Virtually all of the scrap recovered is shipped overseas, where it is processed and returned to this country as refined metals. Several scrap dealers are breaking the battery cells and hand-separating the positive and negative plates. The positive plates, containing 1 to 2 pct cadmium, are smelted in the United States to a high-ferro nickel alloy. The cadmium-rich negative plates are shipped overseas.

As part of its efforts in secondary metals recovery, the Bureau of Mines, U.S. Department of the Interior, pursued this research, which has led to the development of a pyrometallurgical method for recovering metallic cadmium and a nickel-iron residue low in cadmium (fig. 1). This paper is a progress report of the laboratory tests that have been conducted to date. Work is continuing on scaling up the method to test 10- to 20-pound charges of battery scrap. At the time of this investigation, there were only three other known methods: A hydrometallurgical method developed in 1971 by the Bureau of Mines (5), a sulfuric acid leach and electrolytic recovery method (2), and a pyrometallurgical method based on a French patent that fave no details (3).

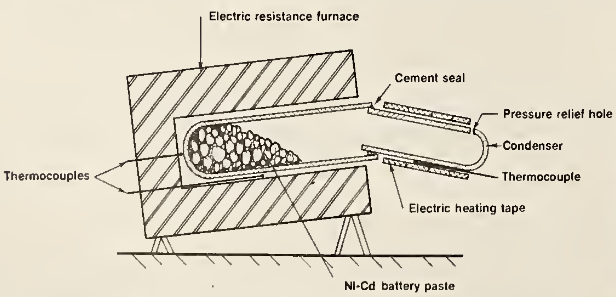

FIGURE 1. - Schematic of retort-condenser system.

This research has progressed to larger scale testing of 10- to 20-pound charges of Ni-Cd battery scrap. The small laboratory tests have successfully demonstrated that the cadmium in the residue can be consistently reduced to 0.05 pct or less by operating at 900° C and atmospheric pressure for 2 hours using 2.5 pct carbon. Although the initial

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large-scale test did not reduce the cadmium to less than 0.1 pct, no difficulties are anticipated in achieving this level and producing a cadmium condensate with low impurities. Work will be continued on the large-scale retort.

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MISCELLANEOUS

CONGRESSIONAL AND AGENCY ROLES IN RESOURCE RECOVERY

by

F. McManus[1]

The conventional wisdom in Washington is that the Congress always reacts to problems and is last to act. Sometimes that is true, but in the case for processing wastes for energy and materials, Congress has clearly been the prod behind the Federal agencies. Lest we get too euphoric, I suspect that this phenomenon exists because it is one of the few environmental issues that no one is opposed to.

As you know, Congress passed the Solid Waste Disposal Act in 1965, which gave rise later to some original work by the Bureau of Solid Waste Management in the Department of Health, Education, and Welfare. Dick Vaughan, our next speaker, was the director of that distinguished Bureau, then in the Public Health Services. Earlier, the Bureau of Mines had been quite active in resource recovery, as evidenced by this series of symposia begun in 1968 and its work in College Park and elsewhere.

Nevertheless, it was the then Senate Public Works Committee which in 1969 and 1970 took the leadership and passed the Resource Recovery Act. It was also during 1970 that President Nixon created EPA and a group of industry and labor leaders founded the National Center for Resource Recovery. Since that time, a great deal of resource recovery progress has taken place, but the Federal role has been much less than the public had eagerly anticipated. The principal culprit is almost universally agreed to be the Office of Management and Budget (OMB). Most seem to agree that OMB analysts, who fear a massive multi-billion-dollar waste-water-type program, are the real villains. I don't agree with that assessment, but that is another subject.

Senator Randolph has sustained an interest in the Resource Recovery Act and its implementation. He held a number of hearings as chairman of the powerful Public Works Committee and as chairman of a special panel after he relinquished the chair of the cognizant subcommittee. When Senator Randolph's renamed Environment and Public Works Committee finished work on its bill in May 1976, no one thought the House would or could pass a similar bill.

A new House subcommittee surprised everybody by acting on a bill introduced by its chairman, Fred Rooney. He and his Subcommittee on Transportation and Commerce staff drafted a new bill, introduced it in June, and held hearings almost immediately. Soon thereafter, the subcommittee and full committee passed the bill. Keep in mind that both the Democrats and Republicans were holding their national conventions during that summer and some members of Congress took vacations.

[1]Editor and publisher, Resource Recovery Report, Washington, D.C.

Among the major changes which the House Committee made were new duties for the Department of Commerce to "encourage greater commercialization of proven resource recovery technology." The subcommittee felt that EPA neither should nor could attempt to regulate as well as promote resource recovery. It was also clear that the members felt there was an important role for the Federal Government in advancing resource recovery and that EPA was not carrying out this role. In the space of 3 weeks the House passed its bill, and staffs of both House and Senate Committees worked long hours to reconcile differences so that the Senate and House each agreed on a bill which President Ford signed on October 21, 1976.

One major deficiency of the law is the failure to provide a specific role for the Department of the Interior. Ironically, many members of Congress and many more Congressional staff had visited the two prototype waste recovery systems which the Bureau of Mines has been operating near College Park, Md., just 10 miles from Capitol Hill.

I describe the genesis of the law to give you a notion of how strongly the Congress feels about resource recovery. Now lest you think the Congressional progenitors went to other things, they didn't! Within 6 months Congressman Rooney held oversight hearings. In 1978 Mr. Rooney held an additional 3 days of oversight hearings, and Senator Randolph has also scheduled 3 days of oversight hearings. Moreover Congressman Brown, chairman of the Environmental and Atmosphere Subcommittee, has scheduled oversight hearings on the research, development, and demonstration portions of the law. Oversight hearings on new legislation are not common. I hope you agree that inadequate Federal agency action in resource recovery does not reflect the views of Congress. One final manifestation of congressional interest has been the work of two congressional agencies, the General Accounting Office (GAO) and the Office of Technology Assessment (OTA).

GAO, Congress' investigatory agency, has undertaken several solid waste-resource recovery studies during the past several years. Two are underway now. One is a comprehensive assessment of bioconversion developments, and the other describes and evaluates various resource recovery systems for municipal solid wastes in four categories: Those which are operating, under construction, in advanced planning, and in some stage of feasibility study. GAO's posture has been that of an advocate for resource recovery.

In the meantime the Office of Technology Assessment is about to release a comprehensive analysis of "resource recovery, recycling and reuse of materials from municipal waste." The study has been underway for more than 2 years and has generated a great deal of expectation and controversy. It assesses transportation rates, tax policy, product disposal charges, the beverage container issue, and incentives and disincentives for recycling.

ASTM COMMITTEE E-38 ON RESOURCE RECOVERY

by

R. D. Vaughn[1]

The concept of recovering material and/or energy from solid waste and reusing these materials as a national resource has been with us for some time now and, as a concept, has joined the ranks of motherhood and the American flag as the thing to do. Since its inception in 1968 this symposium has stressed reuse of waste products from the mineral industry. Federal solid waste legislation, enacted first in 1966 and amended several times since, has always contained references to resource recovery as a desirable concept, and the latest version is even titled the Resource Recovery and Conservation Act of 1976. The real problem is significant implementation of this desirable concept in existing governmental and industrial institutions.

What has prevented this? In the "early" days following enactment of the original Federal solid waste legislation, there was much talk of developing technology to make possible utilization of resource recovery from solid waste otherwise destined to find its way through the Nation's waste streams into some treatment and disposal site such as an incinerator, sanitary landfill, or regretfully too often an open dump. A flurry of activity followed, partially supported by Federal financing, which generally concluded--we have the technology to separate desired materials from waste streams. We also have the technology to convert it to a desired product, although in some cases the cost might be excessive in the competitive marketplace and the dependability economically unsatisfactory. Technology has been demonstrated (3-4) throughout the United States, but still there has been no major move to reuse waste products rather than rely on disposal.

It was then found that economic markets do not exist for the vast material capable of being recovered and reused. Unless someone uses the material, it does little good to separate it merely to create another solid waste accumulation (at considerable cost) which still requires disposal. In some cases, resource recovery processing costs were so high that recovered material could not economically compete with virgin material. In other cases, the overall need for such material does not exist. Concern for conservation of energy has helped solve the first problem, and at least we have a little better handle on the second to help interested parties provide recovered material and energy to U.S. industry. Many parties trying to encourage industry to use recovered materials learned that even when the recovered products from waste are competitive with virgin materials, some industries are reluctant to use them because they do not know how they will perform and have no standards or specifications to serve as the basis for rejection or acceptance of a product, whether it be raw, intermediate, or finished. As Dr. Harvey Alter has pointed out (1), the

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secondary materials industry has employed specification for recycling products for over half a century but generally has been concerned with utilization of scrap from industrial operations rather than recovery of material from mixed municipal waste otherwise destined for disposal. Many feel different forms of specifications must be developed both to encourage recovery and reuse of these materials and to afford the user assurance that he will be receiving a quality product satisfactory to his needs. It was to meet this need that ASTM Committee E-38 on Resource Recovery was established in 1974.

The American Society for Testing and Materials is a management system for the development of voluntary full-consensus standards (2). ASTM standards are formulated by balanced committees with distinct biases according to their interest. The committees are comprised of designated balances of users and producers as well as general interest groups concerned with the particular standard being promulgated. ASTM standards are not company standards, industry standards, professional standards, or government standards, although all these have their place and are considered in ASTM full-consensus standards. Also representatives of industry, government, educational, and public interest groups participate together in the development of ASTM full-consensus standards. The society's work is carried out by approximately 130 standards committees working in such diverse areas as surgical implants, plastic pipe, textiles, and forensic science. One of these committees is ASTM Committee E-38 on Resource Recovery. The scope of this committee is "The development of methods of test, specifications, recommended practices, and nomenclature; the promotion of knowledge, and stimulation of research relating to material and energy resources, recoverable, or potentially recoverable from waste. The waste for resource recovery is here defined as that portion of waste which is collected from industrial, commercial, or household sources destined for disposal facilities. The committee will coordinate its efforts working in this and related fields."

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AN APPROACH TO ENERGY ATTENUATION OF EXPLOSIVE WASTES IN PROCESSING EQUIPMENT

by

A. R. Nollet,[1] E. T. Sherwin,[2] and A. W. Madora[3]

The solid waste resource recovery industry has been growing rapidly in the past decade--spurred by a perceived shortage of raw materials and energy. All existing resource recovery plants that are known to the authors currently employ one of three initial processing steps:

1. Mass burning in incinerators.

2. Wet pulping.

3. Dry shredding.

By far the greatest number of resource recovery plants employ dry shredding as the first processing step.

The use of shredders to process solid waste has increased remarkably in the past 5 years. According to the recent Waste Age Survey (1) of shredding operations in the United States and Canada, the number of reported refuse shredding installations has multiplied approximately fivefold, from 27 shredding plants reported in 1971 to approximately 144 in 1976. Many of these installations shred prior to landfilling, primarily because the Environmental Protection Agency considers that landfilling of shredded refuse can be an environmentally acceptable disposal method that reduces the need for daily soil cover and increases site life. There are several other installations, with numerous others in the planning stage, that shred as a first step in order to obtain a relatively homogeneous waste stream said to be more amenable to automated material handling and other processes associated with resource recovery, incineration, or the preparation of refuse-derived fuels.

Unfortunately, the increased use of shredders for processing solid waste has resulted in frequent explosions within the shredders and adjacent processing equipment, causing great concern for the safety of equipment and personnel. Municipal solid waste is a heterogeneous mixture over which the solid waste processor has little or no control--one may expect daily the delivery of potentially explosive materials such as cans of solvent, cans of gasoline, combustible dust, and commercial or military ordnance. Such materials are readily ignited by sparks from the hammers in the shredder striking metal, or by localized temperature buildup within the shredder.

[1]President, AENCO, Inc., subsidiary of Cargill Inc., New Castle, Del.
[2]Vice president, AENCO, Inc., subsidiary of Cargill, Inc., New Castle, Del.
[3]Director of Public Works, New Castle County, New Castle, Del.

The Factory Mutal Research Corp. recently conducted an assessment on a nationwide basis of the hazards of explosions from the shredding of municipal solid waste for the U.S. Energy Research and Development Administration (3). The summary of this survey indicates the following explosion experience in solid waste resource recovery plants as of the end of 1975:

Total tons processed................	8,295,000
Total explosions....................	97
Explosions causing significant damage	69

This experience represents a frequency of explosions of one for every 85,000 tons shredded; thus, a typical plant processing 1,000 tons per day of municipal solid waste may expect an explosion every 3 months. Fortunately there were serious personnel injuries in only three of the explosions, and even more fortunately, there had been no fatalities to the date of the survey. We are sorry to report that both serious injuries and fatalities have occurred during shredder explosions in the past 2 years.

One of the explosion protection measures described in the Factory Mutual Report (3) and the subsequent paper by Zalosh (2) is the use of a fine water spray (microfog) in the shredder. A rigorous design basis for a water spray system is lacking, but the basic concept is to use the water mist to quench an incipient gas, vapor, or dust explosion before devastating pressures are developed. In terms of an energy balance, the water mist should dissipate the rate of heat generated by combustion in order to prevent continued flame propagation through the combustible gas, vapor, or dust. Since more water droplets promote the rate of heat absorption, an effective water-spray system should consist of small, closely spaced droplets.

The following are conclusions regarding the success of this installation:

It is certain that the microfog system will not significantly attenuate explosions resulting from substances that contain their own oxidant, such as dynamite, military ordnance, and smokeless powder.

It is believed that the microfog system has probably attenuated the forces that are usually experienced during a vapor or dust explosion. It is believed that some of the recent explosions would have caused severe damage had not the microfog system been installed. Plant workers feel more secure with the microfog system installed.

Further testing and operational experience are necessary to define better design criteria than those that we have presented.

It is no longer believed that dry shredding should be the first processing step in new plants.

It is recommended, at a minimum, that existing shredding plants be retrofitted with (1) a well-designed explosion-venting system to allow most of the explosive gases to vent to the atmosphere out of the plant, and (2) some variant of the microfog spraying system.

It is suggested that, in all cases where funds are available, consideration should be given to supplementing the foregoing installations with an explosion detection and suppression device utilizing the halogenated hydrocarbons as the suppressant--extreme care must be taken in the design, location, and method of keeping unplugged the detector tubes.

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DEVELOPMENT OF CONTINGENCY PLAN STANDARDS FOR ACCIDENTS WITH HAZARDOUS WASTE MATERIALS

by

P. C. Knowles[1] and R. C. Tucker[2]

Under the Resource Conservation and Recovery Act of 1976 (Public Law 94-580) enacted by the Congress of the United States, the United States Environmental Protection Agency (EPA) is required to promulgate regulations with regard to the treatment, storage, and disposal of hazardous wastes.

The act is comprised of eight subtitles which are being addressed, at the request of the EPA, by consultants with broad backgrounds and expertise in these fields. At the present time, rules and regulations are in various degrees of completion. Draft regulations should be out in the very near future.

In particular, Subtitle C, entitled "Hazardous Waste Management," addresses the following sections:

3001 Identification and listing of hazardous wastes

3002 Standards applicable to generators of hazardous wastes

3003 Standards applicable to transporters of hazardous wastes

3004 Standards applicable to owners and operators of hazardous waste treatment, storage and disposal facilities

3005 Permits for treatment, storage or disposal of hazardous waste

3006 Authorized State hazardous waste program

3007 Inspections

3008 Federal enforcement

3009 Retention of State authority

3010 Effective date

3011 Authorization of assistance to States

The purpose of the study was to examine a number of management issues pertinent to Section 3004 (1) and (2) of the Resource Conservation and Recovery Action of 1976. The study was divided into four tasks, covering

[1]Partner, Dames & Moore, Boca Raton, Fla.
[2]Associate, Dames & Moore, Washington, D.C.

1. Financial responsibility of hazardous waste management firms,

2. Continuity of operations at hazardous waste sites,

3. Contingency plan standards for accidents at hazardous waste facilities, and

4. Training and certification for hazardous waste management employees.

The various types of hazardous waste disposal facilities, treatment methods, or combinations presently being used include but are not necessarily limited to the following:

Facilities

1. Landfills.
2. Incinerators.
3. Waste lagoons or ponds.
4. Land burial at depth.
5. Deep well injection.
6. Near-surface land burial.

Final Treatment Processes

1. Oxidation/reduction.
2. Neutralization.
3. Chemical degradation.
4. Detoxification.
5. Open burning/detonation.
6. Hydrolysis.
7. Biological degradation.
8. Resource recovery.

Preparatory Treatment Processes

1. Flocculation, sedimentation, and filtration.
2. Precipitation.
3. Ammonia stripping.
4. Evaporation.
5. Centrifugation.
6. Carbon sorption.
7. Solidification and/or fixation.
8. Solvent extraction.
9. Vacuum distillation.

Once the contingency plan standards were developed, five regulatory strategies relating to the approach, scope, and stringency of the standards were evaluated. These strategies were

1. Standard by facility versus uniform standards for all facilities.

2. Federal regulation versus State regulation.

3. Exact and specific requirements versus ad hox flexible requirements.

4. Handling volume limitation.

Under Section 3004 specifications, the design of the facility must also be undertaken with a goal of reducing hazards of material dispersion to the environment. This further reduces the consideration of contingency plan costs, in that protective structures such as dikes, sumps, paving to reduce inflow of spills into ground waters, etc., must be considered regular facility costs, rather than "emergency devices." The facility costs for contingency actions are those for

1. Fire control and suppression systems.

2. Employee protective equipment donned during emergency periods (as contrasted to protective equipment worn during material unloading or handling).

3. Emergency communication equipment.

4. Assessment model costs.

5. Neutralizing, sorbing, or barrier materials used after or during spills.

6. Contingency response costs.

7. Facility diseconomies resulting from contingency considerations, such as inventory limitations.

8. Governmental emergency services for fire, medical, and police actions.

9. Other direct costs for contingency action or protection such as security service during nonoperating hours, standby equipment, standby storage, and demurrage.

Although it is beyond the scope of this paper to list all of the contingency plan standards, evaluations of the three sets indicates the effects and stringency of the facility operation.

Set No. 1--This set of contingency plan standards contains a minimal number of requirements. As such, it closely resembles regulations in effect or under consideration in several States. The effectiveness of this type of regulatory approach relies primarily on the competence of the permit-granting authority in evaluating the effectiveness of proposed plans. The most important advantage in this type of regulation is its ability to cover a wide range of facility types and size. In addition, administrative costs are kept at a

minimum. The major disadvantage of the approach is the lack of guidance provided to the facility operators in preparing contingency plans.

Set No. 2--The standards in this set are markedly more specific and stringent than those presented in set No. 1, and as such would more effectively insure protection of human safety and the environment. An additional advantage of specific contingency plan requirements is the relative ease of determining compliance of submitted plans with the regulations. Associated with these more stringent requirements would be increased costs for implementing the contingency plan. The major disadvantage of this regulatory approach is a lack of flexibility. Unless provisions were made to enable the granting of variances to certain facilities from full compliance with the regulations, the requirements might prove to be excessive for some facilities, particularly the smaller operations. Such possible overregulation presents the threat of suits claiming that the regulations are "arbitrary and capricious."

Set No. 3--This set represents a thorough treatment of requirements to insure optimum protection of human safety and the environment from accidents occurring at facilities employing land burial or lagooning. A combination of specific and flexible requirements are included in the set. As with the standards presented in set No. 2, some provision must be made to enable granting of variances to certain facilities deemed exempt from certain requirements. Again, the inclusion of specific standards facilitates the review of contingency plans by the permit-granting authority.

The three standard sets as well as other variations presently are being reviewed by the EPA. The legal power to promulgate these contingency standards and their degree of stringency rests in the hands of the EPA. Regardless of the contingency plan standards enacted into law, virtually the entire hazardous waste industry, including the chemical industry, manufacturing industry, and mining industry, will be affected in some fashion by Public Law 94-580. These management decisions concerning hazardous waste disposal are a step in the direction of insuring that adequate programs are implemented to safeguard all those people involved in the hazardous waste industry, as well as the public, from any type of accidental release of hazardous wastes to the environment. Hopefully, the resultant EPA rules and regulations will aid the mining industry in developing uniform and effective programs for the collection and containment of hazardous waste materials.

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UTILIZING WASTES AND BYPRODUCTS IN CANADIAN CONSTRUCTION

by

J. J. Emery[1]

The spurt of materials conservation activity triggered by the 1973-74 fourfold rise in petroleum prices has been followed by steady progress as the close interaction of energy, materials and environment was recognized and measures were adopted to insure long-term supplies of the Earth's non-renewable resources. However, current consumption and waste generation statistics still indicate a wide scope for applying a range of conservation measures such as more efficient use of energy and materials, decreased growth in demand, slowing of demographic expansion, development of new materials and manufacturing processes, and recovery and recycling of more wastes and byproducts (1-2, 4-5). It is the purpose of this paper to outline the positive contribution that waste and byproduct utilization in construction makes to materials conservation within the context of current Canadian practice, and to indicate potential trends.

The Canadian construction industry, as a major force in a developing country with long transportation distances and rapid urbanization, requires large per capita supplies of low-unit-cost industrial minerals (mainly aggregates) that are becoming depleted near some urban demand points, or alienated by sprawl (3). Coupled with bulk material requirements, the demand for cementing agents (mainly asphalts and portland cements) and fuels that are becoming increasingly expensive remains firm. These materials and indirect energy considerations also involve a growing concern for environmental protection during all construction-related activity, particularly minerals extraction and thermal processes. At the same time, waste handling and disposal pose a severe problem, given the current emphasis on improved plant conditions and environmental impact. For activities in urban areas, the total cost of disposal to approved sites ranges from about \$5 to \$15 per ton, a cost factor of concern as profit margins on primary products are under pressure. Further, local authorities are tending to limit the dumping of nonmunicipal wastes in landfill sites, and requiring major plants to develop their own disposal areas that must meet stringent environmental controls.

Given this background, waste and byproduct utilization is particularly attractive since it couples resource conservation with attenuation of disposal problems. While numerous research studies, demonstration projects, and current applications have resulted in optimistic projections of the role of wastes and byproducts as materials, some caution is required in the Canadian context as there are several limiting factors to be faced: Current

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economic conditions, agency conservatism, obsolete specifications, and industry structures often result in little demand for a waste or byproduct that shows potential; mineral wastes that could make the largest contribution to bulk material requirements are widely distributed and usually remote from demand points; and the inherent variability of many wastes and byproducts. It is considered that the impact of waste and byproduct utilization on growing bulk materials needs will continue to be small, and the significant contribution will be in terms of recoverable and replaceable energy and special applications. These concepts will be illustrated by outlining applications for pelletized blast furnace slag, surplus sulfur, and steel slag, as shown in the inventory of Canadian wastes and byproducts of major interest as construction materials.

There is still much potential for the utilization of wastes and byproducts as resources to be developed, and the inventories are certainly available. However, optimistic forecasts must be tempered with the harsh reality of both technical and economic constraints that will tend to limit applications to those where energy is recovered or saved, or the waste or byproduct offers performance advantages. An integrated approach by governmental, industrial, and research organizations, taking into account the technical, economic, environmental, and energy factors involved, is needed to foster the new technology required for waste and byproduct management and utilization.

INVENTORY OF CANADIAN WASTES AND BYPRODUCTS OF MAJOR INTEREST AS CONSTRUCTION MATERIALS

(See notes at end of the inventory)

<table>
<tr><th>WASTE/BYPRODUCT</th><th>PRODUCTION</th><th>MAIN USES</th></tr>
<tr><td>1. Blast furnace slags (air cooled and pelletized)</td><td>2.2 x 10^6 metric tons/yr</td><td>Air cooled--aggregate (base PCC, AC), ballast, EF, mineral wool

Pelletized--lightweight aggregate (PCC, masonry), separately ground slag cement</td></tr>
<tr><td colspan="3">23 pct of 1975 pig iron production. Production fairly static. Pelletizing developing rapidly ($\approx$0.2 x 10^6 metric tons in 1976), remainder air cooled. Hamilton (Southern Ontario) major production and utilization area. Use as aggregate covered by ASTM and CSA standards. Separately ground slag cement is covered by CSA A363. Research in progress: partially preground pelletized slag in autoclaved masonry production[1] and pelletized slag in base stabilization.[1] Most of available blast furnace slag utilized. Full utilization anticipated in near future.</td></tr>
<tr><td>2. Sulfur</td><td>16 x 10^6 metric tons surplus currently in storage</td><td>Insulations,[1] AC, concretes, coatings[1]</td></tr>
<tr><td colspan="3">Sulphur Development Institute of Canada (SUDIC) estimate for end of 1975, projection of up to 25 x 10^6 metric tons by 1980. Only surplus byproduct sulfur is considered in context of this paper, mainly from Alberta sour gas fields. Standards for various uses not developed yet. Significant research and development in progress: insulation[1] (sulfur foam and thermal AC), AC (binder system, sulfur/asphalt emulsions, and specialty applications), concrete (hot poured sulfur concrete, additive to PCC,[1] and impregnating agent for PCC), and coatings[1] (mortarless construction, linings, and soil stabilization). Little surplus sulfur now utilized in construction as mainly at developmental stages. More utilization should develop, including international exchange of technology.</td></tr>
<tr><td>3. Fly ash</td><td>1.8 x 10^6 metric tons/yr</td><td>Possolan in PCC, lightweight aggregate,[1] base stabilization,[1] EF</td></tr>
<tr><td colspan="3">CANMET production data. Production increasing rapidly, projection of up to 2.7 x 10^6 metric tons/year by 1980. Currently produced in Nova Scotia, New Brunswick, Ontario, Manitoba, Saskatchewan, and Alberta. Uses generally covered by ASTM and CSA standards. Significant research and development in progress: Portland-pozzolan cements, possolan specifications, and efficient lightweight aggregate production. Little fly ash now utilized ($\approx$90,000 metric tons/year), most goes to disposal sites and/or landfill projects. Fuller utilization anticipated as markets developed.</td></tr>
<tr><td>4. Steel slags</td><td>1.3 x 10^6 metric tons/yr</td><td>Aggregate in AC ballast,[1] EF</td></tr>
<tr><td colspan="3">20 pct of 1975 steel ingot and casting production, less 50 pct recycle to flast furnace burden. Future production increases may be offset by increased recycling. Hamilton (Southern Ontario) major production and utilization area. Uses generally covered by local agency or owner specifications. (Since potentially expansive, care must be taken in EF.) Research in progress: skid resistance in AC and pavement design for steel slag AC. Little steel slag now used outside of works ($\approx$18,000 metric tons/year in AC), in potential demand areas works' applications (EF) takes most. Much greater use in AC anticipated.</td></tr>
</table>

WASTE/BYPRODUCT	PRODUCTION	AMIN USES
5. Demolition wastes (including excavation spoil)	30.4 x 10^6 metric tons/yr	Building demolition--timber, lumber and bricks Excavation spoil--EF Old PCC--aggregate (base, PCC,[1] AC[1]), EF Old AC--aggregate (base, AC),EF

Extension of Hamilton-Wentworth Region data, 1.32 metric tons/capita/year for all demolition, excavation, and construction wastes. Production increasing. Standards for various uses not explicitly developed, but often covered by ASTM and CSA standards for conventional materials. Significant research and development in progress: recycling old PCC as aggregate in PCC and recycling AC. Except for mush use of excavation spoil in EF, most demolition waste goes to disposal sites and/or landfill projects. Significant recycling of AC is anticipated.

6. Nickel and copper slags	≈1.9 x 10^6 metric tons/yr	Aggregate in base construction ballast, EF

Estimated from CANMET data and 1975 nickel and copper production. Production variable, depends on world nickel and copper demand. Sudbury major nickel slag production, and base construction and EF utilization area. Ballast hauled up to 800 km from production points. Uses generally covered by local agency or owner specifications with some ASTM standards. Research in progress: cemented mine backfill using a cementitious blend of ground vitreous nonferrous slag (copper, nickel, lead, etc.) and PC. While ballast applications use a significant amount of current production, generally remote location of nickel and copper slags (and other nonferrous slags) has resulted in considerable stocks in addition to much of current production. More utilization may develop.

7. Bottom ash	≈0.45 x 10^6 metric tons/yr	Aggregate[1] (base, AC) EF

Estimated from CANMET fly ash data, for powerplants only. Production increasing rapidly. Currently produced in Nova Scotia, New Brunswick, Manitoba, Saskatchewan, and Alberta. Standards for various uses not developed yet, but some local agency, owner, ASTM, and CSA specifications and standards applicable. Research in progress: applications in road construction, and influence of soluble sulfates. Except for small quantities used in demonstration projects and some EF, most bottom ash goes to disposal sites and/or landfill projects. Boiler slag, if separate from ash, is widely utilized. More utilization of bottom ash may develop.

8. Cement kiln dust	≈0.45 x 10^6 metric tons/yr	Filler,[1] EF

Estimated from typical waste cement kiln dust production in Ontario and 1975 PC production. While production currently fairly static, large future increases anticipated, particularly with trend to suspension preheater dry process plants (bypass dust). Production in all major urban areas. Use as filler and EF covered by local agency or owner specifications. Research in progress: filler in asphalt mixes and pozzolanic properties. (Much effort on other applications--fertilizer, waste treatment, absorption of SO_2, etc.) Except for relatively small quantities used in EF, most waste cement kiln dust goes to disposal sites and/or landfill projects. More utilization, perhaps even full, will develop as more applications are demonstrated in construction and other applications.

<table>
<tr><th>WASTE/BYPRODUCT</th><th>PRODUCTION</th><th>MAIN USES</th></tr>
<tr><td>9. Bark and sawdust</td><td>≈50 pct of log volume (20 pct bark, 20 pct sawdust, 60 pct chips)</td><td>Bark--recycling (pulp, particle board, fibreboard, fluting medium), roads[1] (frost protection layer, lightweight fill, temporary construction, filter course)

Sawdust and chips--recycling (pulp, particle board, fibreboard), roads (same as for bark, main application is lightweight fill)</td></tr>
<tr><td colspan="3">For each log processed, about half the volume emerges as residues. However, amount not recycled or burnt during steam raising (or direct disposal that is decreasing) is very small proportion. Available quantities decreasing as recycling and fuel potential recognized. Lightweight fill applications covered by local agency special provisions. No known major research or development in progress. Lightweight fill applications use a very small quantity of wood wastes, and it is anticipated that full utilization within the wood industry will be reached.</td></tr>
<tr><td>10a. Glass</td><td>≈1.2×10^6 metric tons/yr</td><td>Aggregate[1] (base, AC), terraco,[1] bricks,[1] foamed and ceramic construction materials,[1] light-reflecting road markings</td></tr>
<tr><td colspan="3">Estimated at 10 pct of municipal refuse (also estimate, 1975). Does not include glass industry waste that is recycled directly. Production trends difficult to predict as much pressure for more returnable containers, coupled with trend towards resource recovery from municipal and industrial refuse. Currently, little waste glass of suitable quality available for use in construction materials, but glass from resource recovery operations that is not recycled may become available in next few years. Standards for various uses not developed yet, but subject of ASTM committee. No known major research or development in progress. (Significant research in past on AC containing waste glass.) Except for very small quantities collected or separated for demonstration projects, most waste glass goes to landfill sites as part of refuse or incinerator residues. Until resource recovery operations develop, little utilization anticipated and recycling will compete.</td></tr>
<tr><td>10b. Iron mine overburden, cobbings, and tailings</td><td>72×10^6 metric tons/yr</td><td>Aggregate (base, PCC, AC), ballast, EF, filler,[1] roofing granules, brick manufacture[1]</td></tr>
<tr><td colspan="3">Estimated from typical CANMET data and 1975 iron ore production. Production fairly static. As with most mining and quarrying wastes, very large stockpiles have built up. 14 iron mines in operation, mainly in remote areas of Ontario and Quebec. Uses generally covered by local agency or owner specifications with some CSA and ASTM standards. No known major research or development in progress. While use as aggregate in AC (traprock), ballast, and roofing granules has involved fairly large quantities (particularly in Ontario), transportation costs limit wide utilization. More utilization may develop.</td></tr>
</table>

WASTE/BYPRODUCT	PRODUCTION	MAIN USES
11. Tires	11×10^6 tires/yr	Aggregate and/or binder component in AC[1] (roads and sport areas)

Estimated from tire replacement data. Production increasing (also waste plastics and other rubber wastes), but applications to capitalize on heat values (fuels and/or process steam) and chemistry may develop to require available production. Production in all areas. Standards for various uses not developed yet except in cases where natural materials replaced. Significant research and development in progress: cryogenic processing and utilization in AC (Strain-relieving layers, binder, and aggregate). Except for small quantities used in demonstration projects, waste rubber not recycled goes to disposal sites. Increased utilization as construction materials not anticipated as recycling, fuel value, and recoverable components will offer strong competition for supply.

WASTE/BYPRODUCT	PRODUCTION	MAIN USES
12. Foundry sand	Not known, probably greater than 1×10^6 metric tons/yr	EF, PC manufacture,[1] pipe bedding, backfill

Production data not available, but quantity probably decreasing as recycling becomes norm. Southern Ontario and Montreal area major production and EF utilization areas. Uses generally covered by local experience with some agency or owner specifications. Significant research and development in progress: use as kiln feed in PC manufacture and specifications for EF, bedding, backfill, etc., applications. At times, large quantities used in EF, but usually goes to disposal sites and/or landfill projects. More utilization should develop.

[1]Potential use, technical feasibility demonstrated.

- AC - Asphaltic concrete.
- ASTM - American Society for Testing and Materials.
- CANMET - Canada Centre for Mineral and Energy Technology.
- CSA - Canadian Standards Association.
- EF - Engineered fill.
- PC - Portland cement.
- PCC - Portland cement concrete.

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POWERPLANT ASH UTILIZATION AND ENERGY CONSERVATION EFFECTS

by

J. H. Faber[1]

Versatility and availability give powerplant ash a tremendous edge over other byproducts in the battle for recycling supremacy.

In fact, ashes are often effectively employed in combination with other industrial wastes, substandard aggregates, or standard materials to produce economical substitutes for more expensive natural aggregates, to reduce the environmental impact of disposal practices, to improve availability, and to reduce energy requirements.

Being a residue of the burning process that transforms coal into electric power, ash has unique properties that require less energy in turning out acceptable construction materials and improving the quality of others in specific applications.

Coal ash is firmly entrenched as the sixth most abundant mineral resource with the 1976 production amounting to 61.9 million tons. Last year's totals, being recorded as this paper is written, are expected to climb to about 65 million tons, and by 1985 the figure will be well in excess of 100 million tons.

Blast furnace slags are listed in 10th position with availability totals in the area of 25 million tons annually. However, the quantities of many other wastes are not readily identifiable, principally because they are not presently in demand nor have they been researched, tested, and/or promoted.

As a Nation, we are the most wasteful people on the face of the globe, but the time is rapidly approaching when we must take care of these materials and find useful applications for them or they will literally cover us up.

In 1976, ash utilization reached an alltime high of 20 pct, or 12.4 million tons. The totals included 5.7 million tons of fly ash, 4.5 million tons of bottom ash, and 2.2 million tons of boiler slag. Early reports for 1977 indicate the overall totals will be even higher. Predictions are that 15 million tons will find its way into the marketplace by 1980, thereby conserving the equivalent of 2 million tons of coal.

Evidence that the overall tonnage will rise is significantly seen in a National Coal Association report that 259 new coal-fired electricity-generating stations are expected to be onstream by 1985. Many of these new plants are being sited to take advantage of developing western coalfields.

An awareness and growing acceptance of ash as a viable construction material is expected to further impact this picture. Likewise, an industrywide movement toward dry handling, collection, and loading facilities should improve the marketability of ash by making greater quantities of ash readily accessible. Sluiced ash requires rehandling to prepare it for sale.

[1]The author is with the National Ash Association, Washington, D.C.

RECYCLING METALS: PROCESSES AND ENERGY REQUIREMENTS

by

C. L. Kusik,[1] S. Malhotra,[1] M. Mounier,[1]
K. Parameswaran,[1] D. Kleinschmidt,[1]
and J. Milgrom[1]

Rather than produce new or "primary" metals from ores, substantially less energy might be used to recover and reuse the large quantities of scrap metals discarded each year by industry and householders. Since only general estimates of potential energy savings have been made in the past, this study was undertaken to gather data on U.S. energy requirements in 1976 for recycling nine metal commodities: iron and steel, aluminum, copper, zinc, lead, titanium, stainless steel, nickel and nickel alloys, and tin. Energy requirements for recycling prompt industrial (new) and obsolete (old) scrap metal have been estimated by major process routes, starting from the first collection center and ending with molten metal, ingots, or other semifinished forms roughly equivalent to a primary metal of similar composition. In addition, energy requirements were estimated for separating municipal solid wastes into four major fractions: Refuse-derived fuel, and magnetic, aluminum, and glass cullet fractions.

In this study energy requirements for major methods of recycling were determined by process step.

For each commodity being considered, typical processing schemes were selected for consideration based upon discussions with Bureau of Mines personnel, consultants, Arthur D. Little specialists, the National Association of Recycling Industries, Inc., the American Iron and Steel Institute, the Institute of Scrap Iron and Steel, the Aluminum Association, and the Aluminum Recycling Association, as well as other trade organizations, and were confirmed with plant personnel during field visits. For some commodities, only one sequence of process steps was selected since it was the only or predominant recycling method, while for others several processes were included for detailed analysis. In addition, one municipal solid-waste flowsheet was selected for analysis to indicate the potential for recovering the components of raw refuse in a form suitable for recycling into the economy.

Scrap metals are normally classified into three categories: Home scrap, prompt industrial scrap, and obsolete scrap. Home scrap is generated within the smelting or refining facility and is recycled directly back into the melting furnaces. Prompt industrial scrap is normally generated within manufacturing operations and is recycled back to the smelting and refining facilities, which may be located some distance from the manufacturing facilities (for example, scrap generated during the manufacture of automobiles or scrap generated in lead battery manufacturing operations). Obsolete scrap (or post-consumer scrap) is old scrap generated at the end of the products' life cycles.

[1]All of the authors are with A. D. Little, Inc., Cambridge, Mass.

Use of the term "new materials" can refer to either new scrap (prompt industrial scrap) or new materials derived largely from ore. To avoid such ambiguity, we have attempted to restrict our terminology, referring to new scrap as prompt industrial scrap and referring to commodities largely derived from ore as virgin materials. This study considered only the prompt industrial and obsolete scrap generated and recycled in 1976. Home scrap use, however, has been identified if it is a typical part of the processing sequence.

As a raw material, scrap is assigned a zero energy content in this analysis. Scrap used as a flux, such as iron units introduced to a secondary lead blast furnace, is charged with an energy value approximately equivalent to producing the commodity from virgin raw materials. Table 1 shows energy values for fuels, other energy sources, and transportation which were derived from previous work done for the Bureau of Mines by Battelle Columbus Laboratories.

TABLE 1. - Energy values used for fuels and energy sources and modes of transportation

	Energy value
Modes of transport:	
Truck..............million Btu per net ton-mile transported[1]..	0.0024
Rail.......................................do.[1].........	0.00067
Water......................................do.[1].........	0.00025
Fuels and energy sources:	
Anthracite coal.....................million Btu per net ton..	25.4
Bituminous coal............................do...........	25.0
Metallurgical coke.........................do...........	31.5
Distillate fuel oil.......................Btu per gallon..	139,000
Residual fuel oil..........................do...........	150,000
Natural gas...........................Btu per cubic foot..	1,000
Electricity........................Btu per kilowatt-hour[2]..	10,500
Steam, low-pressure (per 1,000 pounds steam).....million Btu..	1.0
Steam, at 100 psig (per 1,000 pounds steam)......do...........	1.4

[1]1 net ton = 1 short ton = 2,000 pounds.
[2]Based on approximate fossil fuel equivalent used to generate 1 kilowatt-hour.

Similarly, the energy requirements for materials consumed in recycling (fluxes, oxygen, refractories, etc.) were included in this analysis. In each of the recycling schemes, a transportation distance estimate was made. Such estimates were based upon field visits and industry personnel.

In addition, pollution control, in-plant transportation, and space heating energy use are included in the values reported here.

For the metals considered, amounts of scrap recycled in 1976 are shown in table 2. Potential recovery from municipal solid waste is shown in table 3. It is seen that the potential annual recovery of steel scrap and aluminum scrap from municipal solid waste is roughly equivalent to the new scrap generated.

TABLE 2. - Amount of scrap recycled in 1976,[1] thousand tons

	New[2]	Old[3]	Total
Aluminum	1,030.0	416	1,446.0
Copper	940.0	485.0	1,425.0
Iron and steel[4]	22,629.0	18,515.0	41,144.0
Lead	100.0	570.0	670.0
Nickel and nickel alloys	34.5	23.0	57.5
Stainless steel	208.0	171.0	379.0
Tin	7.7	10.5	18.2
Titanium	8.4	.4	8.8
Zinc	128.0	52.0	180.0

[1]Figures are for scrap consumption unless otherwise indicated.
[2]Prompt industrial.
[3]Obsolete.
[4]Amount of scrap received.

Sources: Bureau of Mines and Arthur D. Little, Inc., estimates.

TABLE 3. - Potential for recovery from municipal solid waste

(Basis: 200 million tons per year refuse-derived fuel from municipal solid waste)

Magnetic fraction (largely iron and steel)..million tons per year..	20
Aluminum....do....	1
Glass cullet....do....	1
Refuse-derived fuel at 7,000 Btu/lb....Btu..	2.8×10^{15}

Table 4 shows energy requirements for preparation of the scrap metals considered in this study. After preparation, a mix of the prepared scrap is generally charged to various melting and/or refining furnaces to produce a semifinished product. Energy requirements for scrap preparation as well as for melting and refining are summarized in table 5.

Since very few commercial municipal solid waste (MSW) resource recovery facilities were in operation in 1976, no processing scheme can be considered "typical" in this relatively new technology sector. Recognizing that good energy data are generally lacking for the large number of processes being proposed, only one system was chosen for analysis. It was recognized that this would indicate only an order of magnitude of energy use, since a more definitive energy study would have to await commercial implementation of the technologies involved on a wider scale.

For the purposes of this study, the Bureau of Mines resource recovery flowsheet has been used. Although no commercial installations utilized the process in 1976, many processes have included portions of the technology and several installations in the planning stage or under construction intend to use a large portion of the process. A commercial-scale process much like the one described is under construction in Rochester, N.Y. Design capacity is

2,000 tons of MSW per day. The energy estimates presented in this analysis are not meant to be representative of current industrial practice. They represent an estimate of the energy that would be consumed by an installation based on the Bureau of Mines flowsheet. Estimate of energy requirements for treating municipal solid waste (MSW) to recover 1 ton of refuse-derived fuel (RDF) associated with recovery of 205 pounds of magnetic scrap, 187 pounds of glass cullet, and 11 pounds of aluminum scrap is about 0.66 million Btu to recover the above mix of segregated scrap fractions.

TABLE 4. - Energy requirements for scrap preparation (including scrap transportation)

Commodity	Scrap preparation process	Million Btu per ton of prepared scrap
Aluminum.......	Clippings by baling and/or shredding.........	0.91
	Borings and turnings by shredding............	3.05
	Aluminum drosses by milling and/or dry screening.	1.06
	Sweating of high-iron scrap..................	9.28
	Sheet and cast scrap by shredding............	1.18
Copper.........	Wire by chopping.............................	1.75
	Wire by incineration.........................	1.67
Iron and steel.	Automotive scrap by shredding................	1.28
	Automotive scrap by guillotine shearing......	.65
	Ferrous scrap by baling......................	.72
	Ferrous scrap by alligator shearing..........	.47
	Ferrous scrap by torch cutting...............	.34
	Home scrap by torch cutting..................	.02
	Crushing of borings and/or turnings..........	.75
Lead...........	Battery breaking.............................	.62
	General lead scrap...........................	.24
Nickel alloys..	Crushing of turnings.........................	4.02
	Preparation of solids........................	2.46
Stainless steel	Shredding of turnings........................	1.93
	Baling of light scrap........................	1.13
	Torch cutting and/or shearing of heavy scrap.	.98
Detinned steel.	Alkaline leaching of prompt industrial tinplate.	2.02
Titanium......	Light scrap by crushing......................	3.98
	Heavy scrap by cutting, caustic cleaning, acid pickling.	4.14
Zinc..........	Dross and/or skimming collection.............	.24
	Sweating auto die-cast scrap.................	4.00
	Sweating mixed die-cast scrap................	2.10

TABLE 5. - Summary of energy requirements by commodity and process in secondary metal recycling including scrap preparation

Commodity and/or process	Product	Million Btu per ton of product
Aluminum:		
Reverberatory melting aluminum scrap	Ingots (casting alloys)....	15.06
Do..............................	Hot metal (casting alloys).	19.60
Reverberatory melting aluminum cans.	Hot metal (can stock)......	8.72
Copper:		
Reverberatory melting No. 1 copper scrap.	Wirebar....................	3.81
Anode furnace and/or electrolytic refining No. 2 copper scrap.	...........do............	17.27
Cupola, converter, and/or electrolytic refining low-grade copper scrap.	...........do............	42.42
Reverberatory melting brass and/or bronze scrap.	Brass or bronze ingots.....	7.09
Iron and Steel:		
Electric arc furnace...............	Continuously cast blooms and/or billets.	8.33
Cupola............................	Castings..................	[1]31.67
Lead:		
Pot melting.......................	Ingots....................	.61
Blast furnace alone (hard lead).....	...........do............	9.65
Blast furnace-reverberatory furnace combination:		
Hard lead from blast furnace......	...........do............	9.61
Soft lead from reverberatory furnace.	...........do............	8.05
Nickel alloys:		
Induction melting (double vacuum)...	...........do............	19.45
Air induction melting.............	...........do............	11.08
Stainless steel: Argon-oxygen-decarburization (AOD).	Strand-cast billets........	9.69
Tin: Tin recovery from detinning leach solution by electrowinning.	Electrolytic tin..........	172.88
Titanium: Vacuum arc furnaces (double melting).	-	([2])
Zinc:		
Distillation retorts...............	Zinc dust.................	24.01
Muffle furnaces....................	Slab zinc.................	18.93
Do.............................	Zinc dust.................	19.71
Do.............................	Zinc oxide................	19.71
Pot melting clean diecastings.......	Cast alloys...............	2.58
Pot melting off-specification diecastings.	...........do............	3.26

[1]4.17 million Btu is accounted for by 0.18 ton of pig iron per ton of castings.
[2]The scrap-to-sponge ratio affects the total energy required.

BUREAU DE RECHERCHES GÉOLOGIQUES ET MINIÈRES

PROCESSES FOR RESOURCE RECOVERY FROM FRENCH URBAN WASTE

by

J. N. Gony[1] and F. Clin[1]

Nowadays, the French industry is relying for nonenergetic supplies (excluding building materials) on national resources for 15 pct and on recycling for 30 pct; the remainder is imported.

It is in a like manner that, in 1974, a trade deficit of more than 8 billion francs resulted, for an overall deficit of 16 billion francs (table 1).

However, during the same year, local communities had to assume the elimination of more than 12 million tons of urban waste, consisting of approximately as much paper and cardboard as imported, as much tin as recycled, and amounts of glass, polyvinyl chloride, and polyethylene much greater than presently recovered.

Moreover, the energetic content of all these materials represents 5 pct of the fuel equivalent consumption of French industry, 80 pct of which could have been saved by recycling (table 2).

It is in such a context that the Bureau de Recherches Géologiques et Minières (BRGM) has stepped in. Well aware of the needs and means of French local communities, it has therefore studied

1. For the largest towns where incineration is the usual mode of elimination, the recovery of the components in the resulting residues,

2. For average size communities, the sorting and beneficiation of raw household refuse, and

3. For smaller agglomerations, the sorting of segregated products.

In the field of household refuse sorting and recovery, the BRGM has, therefore, acquired a set of new techniques offering various solutions to the present-day problems of waste elimination and shortages of nonenergetic resources (fig. 1). It offers better prospects to the local communities concerned, as the case may require, and contributes to bring about a more favorable balance in the global materials supplies for France in the near future.

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TABLE 1. - 1974 statement of supplies in nonenergetic resources for France

Raw materials	National production, thousand tons	Recycled quantities, thousand tons	Imported quantities, thousand tons	Exported quantities, thousand tons	Apparent consumption, thousand tons	Degree sufficiency, pct	Vulnerability	Trade balance, million francs
Iron.........	16,600	10,000	9,000	9,000	26,000	100	Weak.......	+2,400
Aluminum.....	393	141	437	354	617	86	...do......	-98
Copper.......	-	160	390	-	550	30	Strong.....	-3,640
Lead.........	23.5	125	110	16.5	242	61	Average....	-353
Zinc.........	14	141	255	36	374	41	Strong.....	-869
Tin..........	-	2.5	11.7	.4	13.8	18	Very strong	-459
Chromium.....	-	18	140	-	158	11	...do......	-210
Nickel.......	136	9	-	97	48	302	Weak.......	+720
Molybdenum...	-	.5	4.9	.2	5.2	10	Very strong	-107
Tungsten.....	.72	.31	1.81	1.44	1.2	86	Strong.....	-38
Manganese....	-	-	450	250	200	-	Average....	-324
Titanium.....	-	-	59	-	59	-	Strong.....	-219
Silver.......	.17	.17	.76	.40	.70	48	...do......	-392
Platinum.....	-	.0040	.0036	.0026	.0050	80	Very strong	-54
Sulfur.......	1,920	-	800	870	1,850	104	Nil........	-28
Fluor........	352	-	4	119	237	148	Nil........	+34
Potassium....	2,083	-	142	423	1,802	114	Nil........	+120
Salt.........	6,852	-	162	237	6,777	101	Nil........	+6
Phosphates (P_2O_5).	400	-	2,050	-	2,450	17	Very strong	-1,520
Wood, m^3.....	30,931	-	18,667	7,135	42,643	73	Average....	-1,678
Paper pulp...	1,800	1,850	2,000	400	5,250	68	...do......	-1,286
Asbestos.....	-	-	177	-	177	-	Strong.....	-201
Total deficit..	-	-	-	-	-	-	-	-8,286

Source: S. Antonioli. Les Matières Premières en France (Raw Materials in France). Sciences et Techniques, No. 46, 1977, pp. 8-15.

TABLE 2. - Statement of material energy of resources recoverable from domestic waste

(Energy equivalents considered: 1,000 kwhr=2,200 thermies=0.222 ton of oil equivalent [t.o.e.])

Materials	Imported quantities, thousand tons	Recycled quantities, thousand tons	Quantities of products possible of beneficiation in domestic waste, thousand tons	Estimation of consumption of energy needed for processing rejected products		Estimation of energy consumption for recycling rejected products		Estimation of quantity of energy saved by recycling rejected products, thousand t.o.e.
				Unit, t.o.e. per ton	Total, thousand t.o.e.	Unit, t.o.e. per ton	Total, thousand t.o.e.	
Paper and cardboard..	2,000	1,850	2,200	[1]0.22	484	[1]0.04	88	396
Iron................	9,000	10,000	400	[2].78	314	[3].20	80	234
Tin.................	11.7	2.5	2	Tin				
Aluminum............	437	141	25	[4]3.57	89	[4].17	4.2	84.8
Empty containers:								
Glass.............	-	100	800	[2].28	224	.06	48	176
Polyvinyl chloride.	246	-	120	[2]1.70	204	[2].48	58	146
Polyethylene.......	248	-	65	[2]2.07	134	.21	13.6	120.4
Total..........	-	-	-	-	1,449	-	291.8	1,157.2

[1]Centre Technique de l'Industrie des Papiers, Cartons, et Celluloses. Les Fibres Cellulosiques de Récupération (Recovery of Cellulosic Fibers). 1973.

[2]Groupe d'Etude Pour le Conditionnement Moderne. Le Conditionnement Plastique des Liquides Alimentaires (Plastic Conditioning of Liquid Feedstocks). 1975.

[3]Viellard-Baron, B. Recherches en Siderurgie: Économies d'Énergie et de Matières Premières (Investigations in Metallurgy: Savings in Energy and Raw Materials). Courrier de la Normalisation, No. 252, 1976.

[4]Délégation aux Economies de Matières Premières. L'Aluminum (Aluminum). 1976.

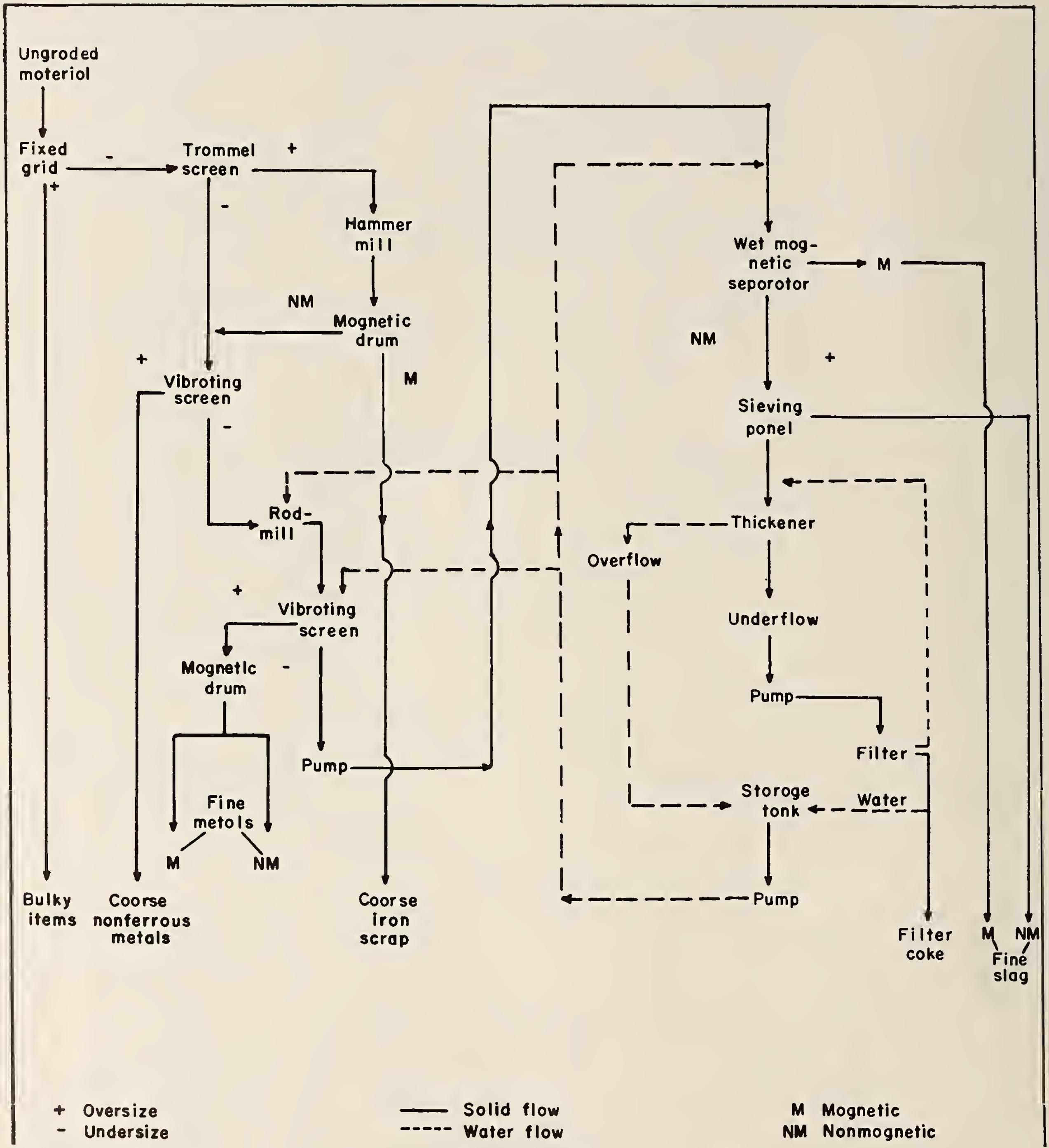

FIGURE 1. - Bureau de Recherches Géologiques et Minières process flowsheet for incineration residues beneficiation.

WASTE PRODUCTS TO FERTILE SOIL--THE COMBINATION OF FLUE GAS DESULFURIZATION SLUDGES AND FINE COAL REFUSE WITH MUNICIPAL WASTE

by

R. C. Freas[1] and R. W. Briggs[1]

Flue-gas desulfurization sludges (FGD) are the byproduct of the scrubbing process used to reduce or eliminate sulfur dioxide emissions at coal-fired electricity-generating stations. Scrubber sludges consist of calcium sulfate and calcium sulfite salts, have a pastelike consistency, low shear strength, and bearing capacity, and are thixotropic. In addition to the calcium sulfite-sulfate reaction products of scrubbing, the solid phase includes various amounts of fly ash and unused scrubbing reagents. The aqueous-phase chemistry varies depending upon the soluble and volatile components of the coal, the scrubbing process chemistry, evaporation, and other concentrating effects during scrubbing.

Coal fine refuse is the minus 28-mesh product of coal cleaning and possesses many of the same physical properties attributed to FGD sludges. Traditionally, it has been handled either as a slurry to be disposed of in refuse ponds or behind an embankment, or it has been formed into a filter cake and transported to some form of a landfill. Both disposal methods are now under close scrutiny by Federal and State officials, and it appears that alternate forms of disposal will have to be found if environmental criteria are to be met.

Thus, it was that Drave Lime Co., with the support of the U.S. Environmental Protection Agency, Project No. F803999-01-0, undertook a research project aimed at developing fertile soils from the combination, stabilization, and disposal of flue-gas desulfurization sludges, coal fine refuse, and municipal waste.

Municipal sludge is the byproduct of municipal sewage treatment and has been a continuing problem for most sanitation districts. One of the primary problems in utilizing waste activated sludge in a combined disposal mode with other waste materials is the extremely low solids content, which consequently results in a very high water contribution to the combined waste products. Since these low solids contents, 0.7 to 8.0 pct solids by weight, were felt to be undesirable, the investigation was restricted to municipal waste filter cake, 17.5 to 25 pct solids by weight.

The pot growth tests with both the FGD sludges and the coal fine refuse demonstrated that the test mixtures would support plant growth. Nevertheless, there was considerable variation in the rates of plant growth between the species used. Ryegrass was the first plant type to germinate, followed by soybeans and then oats. From the comparison of the growth rates, germination

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data, and the plant descriptions, and the soil and plant chemistry, table 1, it is apparent that the plant species employed in the growth tests is of nearly equal importance with the mixture itself. In other words, plant tolerance will affect the success of any seeding done on a synthetic soil resulting from a combination of waste materials.

TABLE 1. - Summary of element occurrence compared with recommended ranges

Element	Crownvetch	Corn	Oats	Soybeans	Ryegrass
Potassium.....	Normal........	Normal...	Normal.....	Low........	Normal.
Calcium.......	......do......	...do....	....do.....	Normal.....	Do.
Zinc..........	Excessive[1]....	...do....	Low to deficient.	....do.....	Low.
Copper........	Low...........	Low......	....do.....	Low to deficient.	Low.
Manganese.....	Normal........	Low......	Normal.....	Normal to low.	Normal.
Iron..........	Normal to high	Normal...	Normal to excessive.	Normal to high.	Normal to high.
Aluminum......	Excessive.....	Excessive	....do.....	....do.....	Do.
Phosphorus....	Normal to low.	Deficient	Very deficient.	Very deficient.	Low.

[1]Crownvetch plants were started in their own potting soil and were delivered to the project where they were then transplanted to the artificial soils. The potting soils were high in zinc, and, therefore, the plants started in them are high in zinc.

Chemical analyses were completed on the plant materials harvested from the outdoor test plots in order to determine those elements that were present in either deficient or toxic quantities. Table 1 summarizes the results of testing for some of the more important elements in relation to their desired level of occurrence. In general, since all of the prepared soil materials were deficient in phosphorus, the plants were also phosphorus deficient. Because of the high pH of the parent materials, most of the plant materials had high to excessive levels of aluminum and iron, while the availabilities of heavy metals were maintained at low levels.

Thus, it was concluded that the high pH of the prepared soils used in this study would reduce the availabilities of high metals in acid materials if they were mixed with the artificial soil. This then would indicate that the FGD-municipal sludge mixtures and/or the FGD sludges alone represent a potential for mixing with acid mine spoils and in strip mine reclamation.

Permeability rates averaged a very low 5.3×10^{-5} cm/sec; nevertheless, leachate samples were collected, when available, and were subjected to chemical analysis. Fourteen major constituents were tested for, all of which proved to be present in quantities that were below critical environmental levels (table 1). However, the pH values and sulfate (SO_4) ion concentrations were relatively high owing to the fact that the FGD sludges were derived from a high-sulfur environment. Because of the low permeabilities of the stabilized sludges, the relatively low volumes of leachates that would be generated,

and the overall leachate quality, it was felt that the potential for significant ground water quality deterioration resulting from the use of these stabilized materials was minimal.

The coal fine refuse-municipal waste test mixtures and the coal refuse alone were very successfully stabilized. In addition, it was possible to germinate and grow several plant varieties, although the stabilized test mixtures were droughty and subject to high plant mortality if not watered regularly. Nevertheless, when stabilized, the fine refuse could be handled with conventional landfill methods and had very low permeability rates. Additional plant material work remains to be done with these soils if their full fertility potential is to be realized.

From the comparison of the plant growth rates, germination data, and plant descriptions, it is apparent that the species of plant selected for growth testing bears significantly on any results achieved. Therefore, it was concluded that additional testing is needed with plants specifically selected for their salt and high pH tolerances. Since plants vary considerably in their ability to accumulate various elements, a wide array of species will have to be tested in order to fully evaluate the potential of the several sample mixes as fertile soils. Nevertheless, this investigation did demonstrate that the selected waste materials could be combined and stabilized to provide a synthetic soil material that would support plant growth.

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